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Surgical Smoke Evacuation Guidelines: Compliance Among Perioperative Nurses

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SURGICAL SMOKE EVACUATION GUIDELINES: COMPLIANCE AMONG PERIOPERATIVE NURSES

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy at Virginia Commonwealth University.

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all surgical smoke. Because of this technology, I dedicate this dissertation to them -- the Stackhouse's – for being the "father and mother" of smoke evacuation throughout the world and for passing this great excitement on to me.

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ABSTRACT

SURGICAL SMOKE EVACUATION GUIDELINES: ASSESSING COMPLINCE AMONG PERIOPERATIVE NURSES

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Smoke (plume) is produced when tissue is cut or coagulated with lasers or electrosurgery devices during surgery. Research has documented that surgical smoke creates a serious workplace hazard for over 500,000 healthcare workers. Toxic gases create an offensive odor, small particulate matter causes respiratory complications, and pathogens may be transmitted within the surgical smoke to the surgical team. Previous research notes that smoke evacuation recommendations are not being consistently followed by perioperative nurses.

The purpose of this study is to determine key indicators that are associated with compliance with smoke evacuation recommendations by perioperative nurses. The Diffusion of Innovation theory by Rogers serves as the model since it describes key

indicators for the adoption of an innovation, including individual innovativeness, perceptions of the innovation attributes, and organizational innovativeness.

A descriptive explanatory/exploratory study was conducted using a validated and piloted survey that consisted of both expert-generated questions and adaptations of previously proven measures. A population of AORN (Association of periOperative Registered Nurses) staff nurse members who have e-mail addresses (N=20,272) was targeted as the universe. A random sampling consisting of 4000 nurses were invited to respond to a web-based survey during a two-month period. There were 777 completed responses representing a 19.4 percent response rate.

The SPSS statistical computer package was employed to analyze the data using frequency/descriptive statistical techniques and bivariate analyses to examine the relationship between the key indicators and compliance with smoke evacuation recommendations. Major findings reveal that specific key indicators influencing compliance include increased knowledge and training, positive perceptions about the complexity of the recommendations, and larger facilities with increased specialization, interconnectedness, and leadership support. The study outcomes are planned to be disseminated via lectures and articles.

Promoting a safe surgical environment is a top priority for perioperative nurses. By identifying key predictors that influence compliance with smoke evacuation practices, a better understanding of the many factors that influence perioperative nurse practices is fostered. Nurse training programs can be developed that directly target and

address these key predictors so that a safe and healthy surgical environment free from surgical smoke can be promoted.

CHAPTER I: INTRODUCTION

Problem Statement

Inhalation hazards have frequented media headlines during the decade between 1999 and 2009. The hazards of cigarette smoke, debris from fires, air contaminants from explosions, the harmful odor from degassing of artificial turf, the hazards of mold and asbestos, and air pollution in confined spaces, such as airplane cabins, are some of the many inhalation hazards that have been highlighted. Since clean air is mandatory for good health (Environmental Protection Agency, 1990), the attention and passion for the elimination of airborne contaminants is not surprising. But one inhalation hazard that has not consistently garnered attention is the smoke pollution within surgical environments. Research has documented that surgical smoke creates a serious workplace hazard for over 500,000 healthcare professionals (Barrett & Garber, 2004). Even though evidence-based smoke evacuation recommendations have been published, compliance by perioperative nurses is still not consistent (Edwards & Reiman, 2008). This study will determine key indicators that are associated with different levels of compliance with smoke evacuation recommendations by perioperative nurses. The results will provide valuable information so that education programs can be developed that address these key predictors that will, in turn, promote smoke evacuation and a smoke-free surgical environment.

When electrosurgical energy or laser beams are used in surgery to cut, coagulate, or vaporize tissue, the cellular contents of the targeted tissue are heated to the point of boiling. The cell membranes explode and cellular contents, known as surgical smoke or plume, are spewn into the air (Ball, 2004). Surgical smoke is listed as a workplace hazard since it causes health problems for surgical team members (Ulmer, 2008). The odor of the plume is caused by toxic gases that may be carcinogenic (Hensman et. al., 1998; Moot et. al., 2007). The extremely small size of the particulate matter can easily be inhaled and cause respiratory problems (Mihashi et. al., 1981; Bigony, 2007). The intact and pathogenic DNA of the smoke particulate matter can cause disease ((Bigony, 2007; Fletcher et. al., 1999; Garden et. al., 2002; Gatti, 1992; Wenig et al., 1993). Research continues to demonstrate the hazards associated with surgical smoke exposure by the surgical team members (Alp et al., 2006; Ball, 2004; Ball, 2007; Barrett & Garber, 2004; Hollman et al., 2004; Ulmer, 1999, Ulmer, 2008). Alp et al. (2006) developed a list of the symptoms that surgical smoke can cause that includes eye irritation, headache, nausea, acute or chronic inflammatory respiratory changes, asthma, chronic bronchitis, lightheadedness, nasopharygeal lesions, throat irritation, and weakness.

The only solution to manage surgical smoke is complete evacuation of the plume (Ball, 2001). There are no mandatory regulations in the United States as of 2009, but the continual emphasis on compliance with voluntary standards shows that the potential danger from surgical smoke exposure is real (Ulmer, 2008). Evidence-based guidelines published by many different organizations and agencies all highly

recommend the use of smoke evacuation methods for any surgical smoke generated (American National Standards Institute, 2005; American Society for Laser Medicine and Surgery, 2007; Association of periOperative Registered Nurses, 2009; ECRI, 2001, National Institute for Occupational Safety and Health, 1996). Even though the technology has been perfected, is effective (Baggish, 1988), and is readily available on the market, smoke evacuation has not become a consistent standard practice for the elimination of surgical smoke (Barrett & Garber, 2004). Smoke evacuation practices are most inconsistent and lacking with the plume created when an electrosurgery device is used (Ball, 2008, Edwards & Reiman, 2008). Smoke evacuation systems are easy to use and cost effective, yet surgical team members, especially perioperative nurses, are sometimes reluctant to use them (Ball, 2007; Edwards & Reiman, 2008). Many surgical team members, including nurses, technicians, surgeons, and anesthesia providers, also fail to realize the hazards of surgical smoke inhalation and exposure or are just complacent about the need to evacuate it (Ball, 2007). This practice of not evacuating surgical smoke coupled with the disregard for the negative consequences of inhaling this plume, increase workplace hazards and promote an undesirable environment for staff members (Ball, 2004).

Even though perioperative nurses fail to comply consistently with smoke evacuation recommendations, no studies have ever been done to determine the key indicators that influence compliance. Therefore, the theoretical framework guiding this study is the Diffusion of Innovations Theory since this model has been used extensively for research that involves the acceptance and adoption of innovations in a variety of

healthcare settings (Rogers, 2003). Diffusion research focuses on conditions that will increase or decrease the chances that a new idea, product, or technique will be accepted into practice (Rogers, 2003), such as compliance with smoke evacuation recommendations. The Diffusion of Innovations model addresses the patterns of adoption of technology but can also be used as a framework for determining characteristics of factors related to the adoption or lack of adoption of healthcare practices (Rogers, 2003). When a practice is adopted, changes occur to an individual as a result of the consequences of the adoption (Rogers, 2003). Compliance with smoke evacuation recommendations is the expected change when smoke evacuation practices are adopted. Since compliance with smoke evacuation recommendations can be considered as the acceptance of a new practice, the Diffusion of Innovations model is very appropriate to use to help understand and explain the characteristics of key indicators that impact compliance.

Innovativeness is "the degree to which an individual...is relatively earlier in adopting new ideas than the other members of a system" according to Rogers (2003, p. 22). Acceptance of new technology, innovative practices, or practice guidelines as described in different research studies, can be impacted by a combination of three independent variables, including a) individual innovativeness (inherent characteristics that contribute to an individual's adoption of an innovation), b) perceptions of the innovation attributes (characteristics of the innovation that influence the adoption rate), and c) organizational innovativeness (organizational forces impacting adoption of an innovation) (Dobbins et al., 2002; Hebert & Benbasat, 1994; Hooper, 2009). The level

of compliance with smoke evacuation recommendations may be impacted by these three independent variables. Therefore, these variables are used as the foundation for the following purpose statement, objectives, and hypotheses.

Purpose Statement and Objectives

The purpose of this study is to determine key indicators that are associated with different levels of compliance with smoke evacuation recommendations by perioperative nurses. The objectives to achieve this goal are:

1. To identify innovativeness characteristics of perioperative nurses (age, education level, years of experience, knowledge, training, presence of respiratory problems) that influence the level of compliance with smoke evacuation recommendations.
2. To identify the perceptions of perioperative nurses regarding the attributes of smoke evacuation recommendations (relative advantage, compatibility, complexity, observability, barriers to practice) that may influence the level of compliance with them.
3. To identify innovativeness characteristics of organizations (descriptors, size, complexity, formalization, interconnectedness, leadership support, barriers to practice) that influence the level of compliance with smoke evacuation recommendations.

Research Questions and Hypotheses

The research questions to be answered are listed below followed by the hypotheses that are influenced by previous research results.

1. What innovativeness characteristics of perioperative nurses influence the level of compliance with smoke evacuation recommendations?

   H1. **As the ages of perioperative nurses increase, compliance with surgical smoke evacuation recommendations decreases.**

   H2. **As the number of years of formal education for perioperative nurses increase, compliance with surgical smoke evacuation recommendations increases.**

   H3. **When the amount of experience, knowledge, and training regarding surgical smoke evacuation increases, compliance with surgical smoke evacuation recommendations increases.**

   H4. **When the incidence of reported respiratory problems by perioperative nurses increases, compliance with surgical smoke evacuation recommendations increases.**

2. What perceptions by perioperative nurses of the attributes of smoke evacuation recommendations influence the level of compliance with smoke evacuation recommendations?

   H5. **When the perceptions of perioperative nurses are favorable regarding the attributes of relative advantage, compatibility, and observability of smoke evacuation recommendations, compliance with smoke evacuation recommendations increases.**

H6. **When perioperative nurses perceive the smoke evacuation recommendations as being complex, then compliance with smoke evacuation recommendations will be low.**

H7. **The higher the nurses rate specific barriers (as an obstacle to complying with smoke evacuation recommendations), the more likely the nurses are not going to comply with smoke evacuation recommendations.**

3. What organizational innovativeness characteristics influence the level of compliance with smoke evacuation recommendations?

H8. **When organizations are large in size, compliance with smoke evacuation recommendations increases.**

H9. **When organizations exhibit greater complexity, compliance with smoke evacuation recommendations increases.**

H10. **When organizations exhibit greater interconnectedness, compliance with smoke evacuation recommendations increases.**

H11. **When organizations show leadership support, compliance with smoke evacuation recommendations increases.**

H12. **When organizations have a high level of formalization, then compliance with smoke evacuation recommendations will be low.**

H13. **The higher the nurses rate specific organizational barriers (as an obstacle to complying with smoke evacuation recommendations), the**

more likely the nurses are not going to comply with smoke evacuation recommendations.

Significance of the Study

Determining why smoke evacuation recommendations are not being consistently followed will provide valuable information to perioperative professionals. This topic has not been extensively studied in the past. This unique study will identify key indicators that influence compliance, including the innovativeness characteristics of the perioperative nurse and the organization. AORN (Association of periOperative Registered Nurses), as the largest organization of perioperative nurses and a recognized leader in the control of workplace hazards, can focus on these predictors to create powerful educational activities and products to persuade the perioperative nurse to evacuate all surgical smoke. AORN has led the surgical community in initiatives such as the "time out" program for proper patient identification, which has become a mandated practice in many surgical facilities throughout the world (Steiert, 2007). AORN has also provided leadership in ergonomics safety, fire prevention, radiation exposure control, and many other activities to minimize workplace hazards (Groah & Butler, 2006). The outcomes of this research on smoke evacuation compliance will provide yet another avenue to promote safety within the surgical environment.

Since the nursing shortage in the early 2000's is negatively impacting every patient care setting, including the surgical department (Seifert, 2000), offering a safe healthcare environment where hazards are controlled provides an incentive for nursing recruitment and retention programs (Shamian & El-Jardali, 2007). Surgical smoke must

be controlled to provide a safe workplace environment. By determining the key indicators that influence compliance with smoke evacuation recommendations, education and training programs can be developed that address these key predictors so that a safe and healthy surgical environment can be promoted. This, in turn, should attract nurses to the perioperative environment, thus decreasing the concerns of nursing shortages in the surgical department.

Delimitations and Assumptions

To prevent this study from being overwhelming, boundaries have been set to narrow the scope of the study. Some of the delimitations or inclusion criteria of this study include:

1. Only active members of AORN are randomly sampled.
2. Only staff nurses who have e-mail addresses are able to participate in the survey.
3. The participant must work in a surgical environment where electrosurgical devices are used.
4. The two-month time period of the study occurs during winter 2008-9.
5. Only nurses who practice in the United States are invited to participate in the survey.
6. The survey is only available on the internet.
7. The participant must read and understand English.

Exclusion criteria for this study include:

1. Those nurses who do not meet the inclusion criteria.
2. Those nurses who served as experts in the survey development.

The assumptions for this study are that the sample is representative of the total population of perioperative nurses, the responses received from staff nurses accurately reflect their professional opinions and practices, and the participants will answer all survey questions openly and with honesty.

Definition of Terms

Defining terms that may have multiple meanings are operationally defined so that the terms are not misunderstood.

Innovativeness: "The degree to which an individual...is relatively earlier in adopting new ideas than the other members of a system" (Rogers, 2003, p. 22). Increased innovativeness for this study means that compliance with smoke evacuation recommendations is greater.

Staff nurses: Professional perioperative registered nurses working with electrosurgical energies and have the potential to be exposed to surgical smoke inhalation hazards.

Evidence-based recommendations: Guidelines based on research that address the protocols and practices for the evacuation of surgical smoke. For this study, the terms guidelines and recommendations are used interchangeably.

Compliance: Adoption of an evidence-based recommendation. For this study, the terms adoption and compliance are used interchangeably.

Organization of the Study

The remainder of this dissertation is organized into chapters that detail each process and section of the research study. Chapter II contains a literature review that summarizes and synthesizes previous studies that deal with the issue of inhalation

hazards, the hazards of surgical smoke, compliance issues, the theoretical model of Rogers' Diffusion of Innovations, and research using the components of individual innovativeness characteristics, perceptions of the innovation attributes, and organizational innovativeness characteristics. Chapter III describes the research design and methodology of the study. The process involved with the random sampling of the population is discussed and the survey tool that is used to gather the data is highlighted. Chapter IV describes the analyses of the data and reports the findings. Chapter V discusses the significance of these findings and provides a summary, conclusions, and recommendations of the study. A reference listing consisting of research and resources on inhalation hazards, surgical smoke hazards, compliance issues, and theoretical framework is found at the end of the chapters. Also there are a number of appendices that offer more detailed information to further support this study.

Summary

The lack of compliance with surgical smoke evacuation recommendations creates an unsafe surgical environment since the inhalation of plume can cause respiratory and other problems for surgical team members. Research has conclusively demonstrated the hazards of surgical smoke as found in the toxic odor and in the invasive particulate matter that most likely can transmit infections. Smoke evacuation recommendations universally promote smoke evacuation methods that involve the use of effective technology and practices to capture and filter surgical smoke. The Diffusion of Innovations model provides a very appropriate framework to identify key indicators that are associated with different levels of compliance with smoke evacuation

recommendations. The following chapter includes a comprehensive literature review on inhalation hazards, evacuation practices, compliance issues, and the theoretical framework to support the methodology and research design of this study.

CHAPTER II: LITERATURE REVIEW

The spotlight on environmental inhalation hazards has focused the problem with smoke inhalation in the surgical arena. Research has repeatedly confirmed the hazards of surgical smoke exposure and the failure of consistent compliance with evidence-based smoke evacuation practices (Bigony, 2007, Edwards & Reiman, 2008, Ulmer, 2008). No systematic investigations have ever been conducted to determine the key indicators related to compliance with smoke evacuation recommendations. The Diffusion of Innovations model can be used to explore the key indicators of individual and organizational characteristics along with perceptions of the smoke evacuation recommendations to determine key predictors for compliance. An in depth discussion about these topics is revealed in this Literature Review section.

Inhalation Hazards

The quest for clean air has been a highlighted goal for quite some time for local communities. The headlines, "Cleaner air linked to longer lives" appeared in a newspaper on January 22, 2009, that revealed reductions in particulate air pollution in the 1980's and 1990's have resulted in an average of five months increased life expectancy in 51 different metropolitan areas (Maugh, 2009). This, in turn, heightens the argument and need for stricter air quality management activities in the promotion of good health.

Campaigns to minimize inhalation hazards require an increased public awareness and sometimes governmental interventions. One of the most common air contaminants is caused from cigarette smoke. A news report on cigarette studies in 2007 notes that long-term exposure to secondhand smoke leads to lung damage (Medscape, 2007). Legislation passed in many states eliminating cigarette smoking in public places helps protect the general population from tobacco smoke contaminants. Clean air laws attempt to minimize secondhand smoke but sometimes are inconsistently enforced (Environmental Protection Agency, 1990, Medscape, 2007). By 2006, public pressure began to require assertive initiatives be taken to ensure compliance with these regulations (Health Ecology Action League, 2006).

Tobacco-related illnesses have been shown to be related to the number of years and the number of cigarettes smoked in a lifetime. An equation can be used to determine the number of "pack years" (number of years smoked multiplied by the average number of cigarettes smoked per day divided by 20). Research has demonstrated that if a person has smoked over ten pack years, tissue damage can be expected (Orrick, 2008).

Other news headlines and interventions regarding the need for clean air include the devastating wildfires that cause inhalation hazards to firemen and the general public. Air pollution has been demonstrated to increase cardiac illness among other conditions (United Press International, 2008). The CDC is so concerned about this hazard that a fact sheet was developed on fire safety that discusses the health threat from wildfire smoke (Center for Disease Control, "Wildfires fact sheet," 2007). The document lists

symptoms of inhalation hazards, the risk factors involved, and how protection can be provided. The CDC also published a prevention guideline "Protect yourself and your family from debris smoke" that refers to the inhalation hazards and protective actions associated with burning debris from hurricanes and floods (Center for Disease Control, Prevention guidelines, 2007).

Headlines describing out-gassing and particle migration from artificial turf have even captured the public's interest regarding inhalation hazards for sports players (New York Times, 2007). Solutions to minimize these risks include the use of alternative products and the avoidance of sports on these fields during high temperatures when out-gassing increases.

Public awareness has been growing on the effect and impact that architecture and structure materials have on minimizing inhalation hazards. A workshop was conducted in July 2007 in Washington DC to initiate preventive actions to "design-out" problems during the planning process of constructing buildings. This "Prevention through Design" (PtD) initiative promotes the concepts of building safer structures by focusing on positive decisions about air quality and inhalation hazards in building designs (National Institute of Occupational Safety and Health, Prevention through design, 2007). Partnerships among major corporations and community groups are being created to address these issues to minimize inhalation hazards.

The battle for clean air is being fought within a variety of professions since serious occupational inhalation hazards continue to be identified with reports of sicknesses, such as respiratory problems and asthma. Animal handlers have reported

increases in allergies and respiratory symptoms from the continual contact and exposure to laboratory animal fur and hair. When personal protective devices with air filtering respirators are used, then the incidence of exposure is decreased (Seward, 2001). A report on "Nurses and Teachers: Worker Health, Worker Concerns" highlights work-related asthma as playing a huge part in worker retention and productivity (Health Ecology Action League, 2006). These and other respiratory illnesses result from the inhalation of chemical and particulate substances in the workplace that have been caused from poor ventilation, biological contaminants, fumes from perfume or air fresheners, odor from tools like markers and photocopier inks, emissions from carpeting, etc. Public awareness about these concerns has increased thus leading to positive actions to remove or control these offending hazards.

Workplace safety, such as indoor air quality, is also highlighted as a major issue by many CDC and NIOSH research studies, articles, guidelines, and recommended practices (National Institute of Occupational Safety and Health, Safety and Health topic, 2007). NIOSH has even published a document, "Guidance for Protecting Building Environments from Airborne Chemical, Biological, or Radiological Attacks," while the National Occupational Research Agenda on Indoor Environment focuses on research that will improve the health of workers in indoor environments (NIOSH, Safety and Health Topic, 2007). A lot of attention has been given to healthy workplace environments to prevent the spread of communicable infections and to explore building-related causes of worker asthma and allergies.

Media coverage on the need for clean air in workplace environments continues to be publicized in headlines. Unfortunately not a lot of attention has been given to the problem with inhalation hazards in the surgical environment. Many times workplace hazards in operating rooms have been overlooked as surgical environments exist "behind closed doors" and therefore, are not in the mainstream of conversation. Long-term exposure to surgical smoke has not been researched and existing literature on workplace safety that addresses compliance with smoke evacuation practices is extremely limited in 2009. Inconsistent smoke evacuation practices can be found in most operating room departments since perioperative nurses are not vigilant about employing appropriate smoke evacuation practices (Edwards & Reiman, 2008). Detailed information about compliance by perioperative nurses, who have the power to employ smoke evacuation methods, and their organizations, that can provide smoke evacuation devices, have not been explored. Research is needed to identify the key indicators of compliance and noncompliance with smoke evacuation recommendations so that intensive educational programs can be created to provide safe workplace environments.

Surgical Smoke Hazards

Approximately 72 million surgical and endoscopic procedures are performed in the United States each year (Center for Disease Control and Prevention, 1998) with an estimated 90 percent of them generating some level of surgical smoke (Ulmer, 1999). Each year over 500,000 healthcare providers are exposed to the hazards of surgical smoke, making this a critical concern for workplace safety (Barrett & Garber, 2004).

When tools, such as electrosurgical energy or laser beams, impact tissue, heat is produced causing cellular contents to boil and the cellular membranes to rupture. The most common "hot" tool used in surgery is the electrosurgery device. Electrosurgical energy produces high frequency electrical current to cut and coagulate tissue. With continual activation of the electrical energy on tissue, cells heat to the point of boiling (100 degrees Centigrade), rupturing the cellular membranes, and spewing the cellular fluid and contents into the air as surgical smoke or plume (Ulmer, 2008). Lasers produce collimated, coherent, and monochromatic light energy that can also heat tissue, causing the cells to boil and explode, thus releasing cellular contents and fluid into the air (Ball, 2004). The mean particle size of smoke particulate produced by electrosurgical energy is approximately 0.07microns in size while laser plume particulate is approximately 0.31 microns in size (Bigony, 2007, Ulmer, 2008). Particles that are smaller than two microns in size can settle in the bronchioles and alveoli (the gas-exchange region of the lungs) when inhaled causing an inhalation hazard (Taravella et al. 2001).

Exposure Hazards

If smoke evacuation practices are not employed, then the surgical team is exposed to the hazards of inhaling surgical smoke (Ball, 2004). Not only have complaints of burning or watery eyes, headache, nausea, and respiratory problems been noted but anecdotal reports have been made showing an increased incidence of asthma and respiratory problems in the experienced perioperative nurse population. This may be linked to the

cumulative effects of inhaling surgical smoke. Table 1 lists the potential health conditions that can be caused by surgical smoke exposure (Alp et al., 2006).

Table 1. Conditions Caused by Surgical Smoke

Acute and chronic inflammatory respiratory problems
Emphysema
Asthma
Chronic bronchitis
Anemia
Anxiety
Cancer
Cardiovascular problems
Dermatitis
Eye irritation, lacrimation
Headaches, lightheadedness
Hypoxia, dizziness
Nasopharyngeal lesions
Nausea, vomiting
Sneezing
Throat irritation
Weakness
Fatigue

Endoscopic Plume Hazards

There is a danger to patients when smoke is created during an endoscopic procedure, such as laparoscopy. In 1997 Dr. Ott conducted research that notes when plume is not evacuated appropriately during laparoscopic procedures, patients are more inclined to be nauseated or complain of headaches in the post anesthesia care unit. When patient blood tests are run, findings reveal elevated levels of methemoglobin and carboxyhemoglobin that decrease the oxygen-carrying capabilities of the red blood cells and thus cause the symptoms of nausea and headache. When surgical smoke is

evacuated during the laparoscopic procedure, elevated levels of methemoglobin and carboxyhemoglobin are not found. This study supports the need to evacuate surgical smoke so patients do not absorb the byproducts of tissue destruction during laparoscopic and other endoscopic procedures.

Odor Hazards of Surgical Smoke

The major areas of concern with surgical smoke that causes it to be a workplace hazard are the odor of the plume, the size of the particulate matter, and the potential viability of the smoke contents (Ball, 2007). The odor is caused from the release of toxic gases, such as benzene, acrolein, formaldehyde, polycyclic aromatic hydrocarbons, and carbon monoxide just to name a few (Hensman et al., 1998). Experts estimate that there may be over 600 more compounds and gases that have yet to be identified (Hoglan, 1995). Some of these toxic gases have already been shown to be carcinogenic, such as benzene, which also has been documented to be a trigger for leukemia (Ulmer, 2008). Even though these toxins exist in trace amounts, the surgical team inhales them repeatedly so cumulative exposure may become a problem (Ball, 2001).

Particulate Matter Size of Surgical Smoke

The size of the particulate matter in surgical smoke was investigated in a classic original study that conclusively documents over 77 percent of the plume contents being 1.1 microns in size and smaller (Mihashi et al.,1981). When this small particulate is inhaled, respiratory problems result as shown in research conducted by Dr. Baggish et al. on laboratory mice (1988). Exposure to the small particulate can lead to hypoxia and

pulmonary congestion with bronchial hyperplasia and hypertrophy (Baggish et al., 1988). Other research demonstrates respirable particles even exist in the plume when excimer laser (LASIK) procedures are performed on the eye during corneal sculpting (Taravella et al., 2001). Even though standard surgical masks are worn that filter five micron in size particulate matter, the particles in surgical smoke easily can pass through these masks and be inhaled by the surgical team (Ball, 2001). Since the mean diameter of electrosurgical smoke particles are smaller than those within laser plume (Ulmer, 2008), this study is focuses on the hazards involved with electrosurgery smoke inhalation. .

Studies have been conducted to determine the distribution of surgical smoke particulate in the operating room. Results have revealed that particle concentration levels can remain high throughout the operating room as surgical smoke can easily travel distances from the site of the smoke generation (Brandon & Young, 1997). Since operating rooms require increased air movement and exchanges of air, particulates from surgical smoke can be disseminated quickly throughout the operating room when proper smoke evacuation practices are not employed. The circulating nurse who is at a distance from the surgery site can be exposed to as much surgical smoke as the scrubbed team.

Viability of Surgical Smoke

The viability of the surgical smoke contents that could transmit disease is still being debated and has yet to be conclusively demonstrated (Barrett & Garber, 2004). However, Dr. Jerome Garden et al. in 1988 demonstrated that when bovine

papillomavirus is vaporized using a carbon dioxide laser, intact viral DNA can be extracted from the surgical smoke. When this viral DNA material is injected into another part of the cow, the same papilloma lesions appear (Garden et al., 1988; Garden et al., 2002). Since this papillomavirus was not the result of the cow breathing in the surgical smoke, transmission through inhalation has not been demonstrated. Further studies are needed to validate the transmission of viral and bacterial contamination through inhalation.

Sawchuck et al. (1989) noted the presence of intact virions in electrosurgery smoke and was able to demonstrate their infectivity. Depending on the type of tissue being ablated, the mutagenicity of electrosurgery smoke has been found to be similar to that of cigarette smoke (Tomita et. al., 1989).

Anecdotal reports have been published that raise the concern for potential airborne transmission of pathogenic organisms within surgical smoke (Ball, 2001, Barrett & Garber, 2004). For example, a report was published about a 44-year old surgeon in Norway who developed laryngeal papillomatosis. He used the laser to vaporize condyloma (venereal warts) on many patients. He inhaled the surgical plume since smoke evacuation methods were not employed. After years of exposure to this surgical smoke, the surgeon became hoarse. When he sought medical care, conclusions were made that connected his patients' viral lesions as the source of the viral contamination invading his own vocal cords (Hallmo & Naess, 1991). Another example is a report about verrucae developing in unusual sites, such as in the anterior nares of laser operators (Volen, 1987). This strongly suggests that transmission of

airborne contaminants can easily occur. These examples, along with other reports, support the high potential for airborne transmission of viral DNA in surgical smoke no matter if lasers or electrosurgical devices are used (Ball, 2004; Ball, 2001; Barrett & Garber, 2004).

Compliance

Surgical smoke can be managed if appropriate smoke evacuation methods are employed as described in evidence-based clinical practice guidelines (Ball, 2001). Effective smoke evacuation devices are available today to remove the hazardous surgical plume from the air if used appropriately and if used consistently. Research conducted by Dr. Baggish et al. (1988) concluded that smoke evacuation methods that remove smoke particulate matter down to 0.1 micron in size are effective in minimizing inhalation hazards. The Duke survey published in 2008 notes that there was inconsistency with smoke evacuation practices with less than half of the responders using effective engineering controls to remove surgical smoke (Edwards & Reiman, 2008).

Smoke Evacuation Methods

Evidence-based recommended practices direct the use of smoke evacuation methods depending on the amount of plume generated (AORN, 2009). When small amounts of surgical smoke are created, an in-line filter can be placed within the line between the wall suction outlet and the suction canister to capture the small particulate matter while preventing the particulate from occluding the suction line. When large amounts of plume are generated, an individual smoke evacuator is needed to filter the

plume by removing the odor with a charcoal filter and the small particulate matter with an ULPA (ultra-low penetration air) filter. Both of these smoke evacuation systems are easy to use, cost effective, and available yet surgical team members, especially perioperative nurses, are sometimes reluctant to use them (Ball, 2007). Using the suction line only (without an inline filter) to evacuate surgical smoke is not an appropriate smoke evacuation method. The practice of not properly evacuating surgical smoke coupled with the disregard for the negative consequences of inhaling surgical smoke, causes an increase in workplace hazards and promotes an undesirable environment for staff recruitment and retention (Ball, 2008).

The research conducted by Dr. Doug Ott has resulted in concerns about the hazards of surgical smoke during laparoscopic procedures (Ott, 1997). The presence of surgical smoke in the abdomen not only obscures visibility but the toxic gases can be absorbed by the patient causing other problems. Hand control suction devices, purge systems, and smoke evacuators have been designed to provide gentle evacuation of the plume during laparoscopic procedures without destroying the pneumoperitoneum. A high flow insufflator is recommended so that any gas evacuated can be replaced rapidly.

Laser verses Electrosurgical Smoke Evacuation

Since the mid 1980's, when laser technology in healthcare was first introduced, courses have been conducted to educate physicians, nurses, and technicians on safety measures and the appropriate application of laser energy. Proper smoke evacuation has been a major component of these safety presentations, therefore, many healthcare providers will consistently evacuate the plume created when the laser is used to cut,

coagulate, and vaporize tissue (Edwards & Reiman, 2008). In contrast, electrosurgery, which has been around since the 1920's, has not been the focus of specialty courses; therefore, safety education specifically on the hazards of electrosurgical smoke have been lacking. Many surgical team members will evacuate laser plume while evacuation of electrosurgery smoke still is not being consistently accepted and practiced (Ball, 2008). The Duke survey published in 2008 with 623 responses reveals that there is a higher frequency of smoke evacuator use during laser procedures for condyloma vaporization (83 percent) than during comparable vaporization of condyloma surgeries involving an electrosurgery device (59 percent) (Edwards & Reiman, 2008). A serious limitation in the Duke study is that the choices of smoke evacuation methods offered only included "smoke evacuator, wall suction, or none." Another option of an appropriate smoke evacuation method should have included the wall suction with an inline smoke filter. Since this option was not offered, the results of this study may be skewed or may not allow the findings to be generalized to the population of surgical team members.

In 1989 Dr. Tomita and his Japanese colleagues compared the hazards of surgical smoke to those of cigarette smoke. When a CO_2 laser was used to vaporize one gram of tissue, the effect of breathing in the resultant plume was compared to the hazard potential of smoking three unfiltered cigarettes. When electrosurgery was used to vaporize tissue, the results compared the smoke inhalation hazards to that of smoking six unfiltered cigarettes (Tomita et al., 1989). This research demonstrates that electrosurgery plume may be more hazardous as compared to laser smoke but actually

both types of smoke are very similar and can cause identical inhalation hazards (Tomita et. al, 1989).

Even though research findings suggest that there may be differences between laser plume and electrosurgery smoke, both should be treated the same and properly evacuated (Bigony, 2008). Since laser plume is more consistently evacuated during surgery (Ball, 2008, Edwards & Reiman, 2008), this study focuses on the evacuation of surgical smoke created when electrosurgery devices are being used.

Smoke Evacuation Recommendations

In response to the noted inhalation hazards of surgical smoke, professional organizations and agencies have published recommended practices, position statements, and guidance papers reflecting the need to properly and consistently evacuate surgical smoke. Organizations such as the American National Standards Institute (ANSI), the Association of periOperative Registered Nurses, the American Society for Laser Medicine and Surgery, and the ECRI have adopted position statements and evidence-based recommended practices directing the use of local exhaust ventilation (smoke evacuators or suction devices with inline filters) for the evacuation of surgical smoke (American National Standards Institute, 2005; American Society for Laser Medicine and Surgery, 2007; Association of periOperative Registered Nurses, 2009; ECRI, 2001). Government agencies, including the National Institute for Occupational Safety and Health (NIOSH) and the Occupational Safety and Health Administration (OSHA), have published evidence-based statements supporting the use of smoke evacuation practices (NIOSH, 1996). There are no mandatory regulations in the United States in 2009, but

the continual emphasis on compliance with voluntary standards highlight the potential danger from surgical smoke inhalation (Ulmer, 2008).

Lack of Compliance

Even though research supports the hazards of surgical smoke and evidence-based recommended practices advocate the use of smoke evacuation methods, the evacuation of surgical smoke practices have not been adopted as rapidly as predicted, thus fostering an unsafe workplace environment from this inhalation hazard (Ball, 2007). Andersen raised a provocative question in 2005 (p. 103) about the practices and attitudes on surgical smoke, "In hindsight, will health care professionals be embarrassed about their cavalier attitudes toward surgical smoke as they once were with cigarette smoke?"

Many reasons may be responsible for the lack of adoption and compliance with evidence-based recommended practices. Healthcare providers may be indifferent to changes needed to adopt new practices, such as employing smoke evacuation methods (Ball, 2007). Those responsible for purchasing devices and supplies may not realize the impact of not providing smoke evacuation systems for every operating room so limited inventory or outdated smoke evacuation devices may be the reasons for not evacuating surgical smoke. The lack of knowledge about the negative consequences of inhaling surgical smoke is probably one of the most common reasons for not evacuating surgical smoke. The health belief model theorizes that a person will take action if he or she feels that a negative consequence can be avoided (Rosenstock et al., 1994). Therefore, education is paramount to encourage smoke evacuation practices.

Another reason for noncompliance with surgical smoke evacuation recommended practices may be the lack of administrative support (Marchionni & Ritchie, 2007) or mandates by the surgeon that smoke evacuation is not necessary (Edwards & Reiman, 2008). Also complaints of the smoke evacuation tubing being bulky and difficult to use may be a reason for non-compliance along with the added noise that some smoke evacuators produce. (Edwards & Reiman, 2008).

Since there is a lack of research identifying consistent predictors that link compliance with smoke evacuation recommendations, this study will provide valuable information to fill that void. The results of this study will determine the key indictors for compliance that, in turn, will lead to a greater understanding of nurse acceptance of evidence-based recommendations. This information will provide a strong foundation upon which education and training programs can be created to ensure compliance with smoke evacuation recommendations and thus, promote a safer workplace environment for perioperative nurses.

The hazards of surgical smoke, as reviewed in this section, are supported by numerous studies, with some that have been in existence for years. Industry has realized the dangers associated with surgical smoke and has created smoke evacuation systems that adequately and effectively remove plume at the surgical site. Professional organizations and agencies also realize the risks of surgical smoke and have provided valuable recommendations to guide the surgical team in smoke evacuation practices. Unfortunately adoption and compliance are still lacking thus resulting in undue exposure to surgical smoke by perioperative professionals (Edwards & Reiman, 2008).

Previous research results, as noted in this section, highlights the hazards of surgical smoke along with the lack of adherence to smoke evacuation recommendations that, in turn, illustrates the great need to determine the key indicators associated with compliance.

Theoretical Framework

The theoretical framework guiding this study is the Diffusion of Innovations Theory that has been used many times as the foundation of research involving the acceptance and adoption of innovations in a variety of healthcare settings (Rogers, 2003). Research using this model focuses on the conditions or characteristics that influence the acceptance or adoption into practice a new idea, technique, product, or procedure, such as the practice of evacuating surgical smoke when complying with evidence-based surgical smoke evacuation guidelines. Even though the Diffusion of Innovations model addresses the patterns of adoption of technology, it can also be used as a framework for determining innovativeness characteristics of individuals and organizations related to the adoption or lack of adoption of healthcare practices (Rogers, 2003). When a practice is adopted, behavior changes occur as a result of the adoption. The behavior change noted in this study is compliance with smoke evacuation recommendations indicating the adoption of smoke evacuation practices.

Diffusion is the "process in which an innovation is communicated through certain channels over time among the members of a social system" (Rogers, 2003). An innovation is defined as "an idea, practice, or object that is perceived to be new by an individual or other unit of adoption" (Rogers, 2003, p. 12). The stages of adoption of

an innovation include knowledge (understanding the issues and an understanding of the innovation), persuasion (forming a positive attitude toward the innovation), and decision or adoption (commitment to acceptance) (Clarke, 1999). Innovativeness alludes to adoption of new ideas, technology, or practices (Rogers, 2003). When a practice is adopted, behavior changes result, such as complying with evidence-based recommendations. For this research, key indicators or characteristics are explored that influence adoption and, therefore, compliance with surgical smoke evacuation guidelines.

Variables

The independent variables that serve as the key indicators for compliance with surgical smoke evacuation recommendations are patterned after the variables revealed in studies based on Rogers' Diffusion of Innovations. Adoption of new technology or compliance with recommendations can be influenced by the three independent variables that follow (Dobbins et al., 2002; Hebert & Benbasat, 1994; Hooper, 2009, Rogers, 2003):

1. Individual innovativeness characteristics
2. Perceptions of the innovation attributes
3. Organizational innovativeness characteristics

Compliance with recommendations is the dependent variable that may be influenced by the above three variables. The dependent variable includes eight different surgical procedures with three different smoke evacuation options, including the use of a smoke evacuator, an inline filter on a suction line, or suction only. The study

participant responds with the frequency of use of each smoke evacuation option according to ranges that are defined. In this study, the adoption of the practice lies on a continuum from failure to comply with smoke evacuation recommendations to full compliance with smoke evacuation recommendations. The use of a smoke evacuator or an inline filter on a suction line represent compliance with smoke evacuation recommendations while responding with the suction only option reflects failure to comply with smoke evacuation recommendations.

The independent variables are categorized and exhibited in Appendix A. Results from the many studies that include these variables are explained in more detail in the following sections. These outcomes are then used to formulate the previously listed hypotheses that have been set for this study.

Individual Innovativeness Characteristics

Individual innovativeness includes the characteristics of the individual that leads to or influences the adoption of new practices (Hebert & Benbasat, 1994). These characteristics can include knowledge, experience, age, education level, and training (Dobbins et al., 2002; Marchionni & Ritchie, 2007; Rogers, 2003). Research that looks specifically at these characteristics and their influence on compliance with smoke evacuation practices by perioperative nurses is nonexistent. Research is available though that correlates various individual characteristics with the adoption or acceptance of new technology or research-based recommendations. Age, educational preparation, and length of service or experience in the nursing profession are variables often considered when determining adoption of technology by individuals (Hebert &

Benbasat, 1994). Younger, more highly educated personnel with more experience usually more readily adopt technology or use evidence-based recommendations (Hebert & Benbasat, 1994; Lia-Hoagberg et al., 1999; Rivers et. al., 2003; Vaughn et al., 2004). Brancheau and Wetherbe (1990) report that early adopters of spreadsheet software are younger, more highly educated, and are more apt to be opinion leaders (individuals whose opinions were requested a lot).

Research conducted by Rivers et al. (2003) support that adequate training of nurses is a positive predictor of their acceptance of an intravenous catheter safety needle device. The nurses' background and experience with the device impact favorably on its acceptance. The study also found that nurses who work in the hospital for a shorter period are more likely to accept the device. This research indicates that despite the hospital declaring that the safer needle devices are mandatory to use, one of seven nurses do not always use the safer needle device (Rivers et al., 2003), which is a concern. Another study notes though that nurses with less experience are least likely to use evidence-based guidelines in their practices (Lia-Hoagberg et al., 1999). Increased frequency of education in a study was found to be a predictor of adherence to safe needle precautions (Vaughn et al., 2004). The acceptance and compliance with surgical smoke evacuation recommendations may parallel the results of this study.

Perceptions of Smoke Evacuation Recommendation Attributes

Perceptions of the attributes of an innovation or practice also can impact its acceptance according to Rogers (2003). These perceptions include (Rogers, 2003):

1. Relative advantage (the level that the innovation or practice is perceived to be better than what exists)
2. Compatibility (consistency with existing practices and values, past experiences and needs)
3. Complexity (intricacy of understanding and use of the technology or practice)
4. Observability (visible benefits of the use of the innovation or practice).

Perception of the attributes of the smoke evacuation recommendations can be expected to influence compliance. Research supports that the ease that technology or practices are used contributes to its successful implementation. Hebert and Benbasat (1994) demonstrated that the strongest predictors of technology adoption were compatibility, relative advantage, and observability with approximately 77 percent of the variance of technology adoption being explained by these three variables. This is similar to Moore and Benbasat's study (1991) that supports compatability and relative advantage as being strongly predictive of technology acceptance. Hebert & Benbasat (1994) also suggest that relative advantage (the benefits and advantages of using the new technology over existing practices) should be clearly identified by organizations in developing strategies for adoption. Tornatsky and Klein (1982) determined from their research that prominent factors influencing research utilization are relative advantage and compatibility.

Grilli and Lomas (1994) found that the level of complexity as an attribute of an innovation is inversely proportional to its adoption. Therefore, the greater the complexity, the lower the compliance rate of use can be expected.

Complex guideline structure has also been shown to be an obstacle to a guideline's implementation as it prevents immediate application to practice (Lia-Hoagberg et al., 1999). Brand et al. (2005) conducted a study that notes the lack of consistency within the recommended practice also can be a barrier to implementation. The more complex and daunting the recommended practice is, less understanding will prevail, thus leading to lack of acceptance into practice.

Organizational Innovativeness Characteristics

The organization where nurses practice must be considered when best practices are expected to be delivered based on research outcomes (Marchionni & Ritchie, 2007). Research indicates that the predominant barrier to nurses using research is related to the organization (Kajermo et al., 2007). Even though there are few studies on the influence of organizational factors on the adoption of innovations, there is beginning evidence that guideline implementation is influenced by organizational culture and leadership factors (Marchionni & Ritchie, 2007).

Estabrooks (2003) has done extensive research on barriers to implementation of evidence-based practices focusing on the individual care provider while stating that expanded research with other focuses should be conducted. Further research by Estabrooks et al. (2007) attempts to predict research use by nurses taking into account different organizational factors. Results note that specialty and organization-level factors contribute little as compared to individual characteristics when assessing research utilization. Estabrooks continues to state that dealing with and unscrambling

the influences of organizational complexities at different levels is a very complex process and requires a lot of time and money (Estabrooks et al., 2007).

Rogers notes that certain internal organizational characteristics have an effect on organizational innovativeness and the acceptance of innovations. The characteristics having a positive effect on adoption rates are size, complexity, and interconnectedness (Rogers, 2003). The characteristics having negative effects on innovativeness are centralization and formalization meaning that when power is focused in fewer hands along with formal structures and bureaucracy being enforced, then the innovativeness of the organization suffers (Rogers, 2003).

Characteristics of an organization (complexity and size) are shown by other studies to contribute to the successful implementation of new technology (Hebert & Benbasat, 1994). A study by Estabrooks et al. (2007) notes that hospital size is a significant determinant of the utilization of research-based guidelines. Larger hospitals usually have a higher level of research utilization in practice.

Interconnectedness is the "degree to which the unit is linked by interpersonal networks" (Rogers, 2003). Research shows that a variety of techniques are successfully used by organizations to connect to care givers in the dissemination of evidence-based practice guidelines (Davis & Taylor-Vaisey, 1997). A study by Brancheau and Wetherbe (1990) notes that interpersonal channels of communication are needed for the successful adoption of technology. Studies by Bero et al. (1998) and Grimshaw et al. (2001) verify that a multifaceted educational approach (increased interconnectedness) is usually more effective in changing practices. Some studies note though that even with

intensive dissemination techniques, sometimes guidelines are just not fully implemented into practice (Waddell, 2002) or are only partially implemented (Grimshaw et al., 2004).

Interconnectedness and collaboration are very similar in meaning and scope. Since instruments that measure interconnectedness are limited, instruments measuring collaboration have been used with great success (Baggs & Schmitt, 1997). The Collaboration and Satisfaction about Care Decisions (CSACD) created by Baggs and Schmitt (1997) is widely used in many different healthcare studies. Hooper (2009) adapted the CSACD tool to determine the interconnectedness and collaboration between nurses and physicians in the surgical environment. This adaptation serves as a model for the development of a survey tool for this study that reflects collaboration between the perioperative nurses and surgeons regarding smoke evacuation recommendations.

There is beginning evidence that "learning organizations" (such as academic settings) that eliminate barriers to learning and actively promote education are more responsive to innovation adoption (Marchionni & Ritchie, 2007). Senge (1990) describes that learning organizations empower individuals to achieve a sense of mastery in accomplishing goals. Rycroft-Malone et al. (2002) propose that research use in healthcare (such as evidence-based recommended practices) is more apt to occur in learning organizations, such as academic settings.

The impact of effective leadership is often considered when determining adoption rates of innovations. One definition of leadership is the process of influencing individuals to achieve common goals (Huber et al., 2000). Effective transformational

leadership that communicates the organization's values to achieve cohesion among staff members is linked with successful change processes and should be explored more to determine its influence in the adoption of evidence-based guidelines (Marchionni & Ritchie, 2007). Hebert & Benbasat (1994) suggest that influential individuals (such as leaders) should be identified to include them in the change process of technology adoption. Pettigrew et al.'s (1992) Content, Context, and Process model of strategic change notes that key people in leadership positions play significant roles in guiding change.

The Barriers to Research Utilization Scale developed by Funk et al., based on Rogers' Diffusion of Innovations model, has been used to assess nurses' insight on the barriers to the use of research findings in practice (Funk et al., 1991). Four factors addressed in the Funk scale include characteristics of the participant, characteristics of the organization, characteristics of the innovation, and characteristics of communication of research. This scale is used to determine the barriers to research utilization in a study by Hutchinson & Johnston (2004). The greatest barriers perceived by nurses are the lack of authority to change practices, time constraints, lack of support to implement changes, and lack of awareness of available research literature. Using this survey scale within a magnet community hospital, a research study compared the results to other studies noting that the barriers to research utilization are less within the magnet hospital (Karkos & Peters, 2006).

Identifying predictors of obstacles to adoption of innovations are significant to determine activities to promote evidence-based practices (Kajermo et al., 2007).

Kajermo et al. (2007) report lack of leadership support and having no academic degree are perceived barriers to the implementation of research-based practices. Lia-Hoagberg et al. (1999) also note that supervisor expectation and support in using research-based guidelines in clinical practice is a motivating factor for individual nursing practices. Management support for safety was shown to be a positive predictor of adherence to safe needle precautions in a study by Vaughn et al. (2004). A summary reported by Rycroft-Malone (2007) finds that responsive administration leads to greater staff autonomy and support for innovation utilization. A study comparing research utilization among medical and surgical nurses report the top two perceived barriers as being management not allowing the implementation and the nurses not feeling as though they have enough authority to make the changes (Parahoo & McCaughan, 2001). Hutchinson and Johnston's study (2004) report that great barriers to research utilization as perceived by nurses include lack of support for the implementation of research findings, lack of awareness of available research literature, and lack of authority to change practices.

The availability of safety equipment was found to be a predictor of consistent adherence of its use in a study by Vaughn (2004). Results from a study conducted at Duke University, note that the participants reported that lack of smoke evacuation devices, older smoke evacuators, and malfunctioning smoke evacuators prevented compliance with smoke evacuation practices (Edwards & Reiman, 2008). Also perceptions of the equipment noise, reliability, convenience, and cost may affect its consistent use.

The Diffusion of Innovations model has provided a firm foundation for many studies in the past that explore the characteristics and attributes associated with the acceptance of new technology or compliance with research-based practices. Results of these studies, as reviewed in this section, offer insight to anticipate key indicators that promote or discourage compliance with smoke evacuation recommendations.

Summary

The diagram in Appendix B depicts the model based on Rogers' Diffusion of Innovations that illustrates the independent and dependent variables of this study. The independent variables are the individual innovativeness characteristics of perioperative nurses (age, education level, experience, knowledge, training, and presence of respiratory problems), the perception of attributes (representing the relative advantage, compatibility, complexity, observability of smoke evacuation recommendations and barriers to practice), and the organizational innovativeness characteristics (descriptors, size, complexity, formalization, interconnectedness, leadership support, and organizational barriers to practice). The dependent variable is the level of compliance with smoke evacuation recommendations.

The inhalation of surgical smoke has been demonstrated to be hazardous as supported by multiple research studies as noted in this chapter. Research-based smoke evacuation recommendations have been widely publicized by numerous organizations and agencies that promote smoke evacuation practices to adequately remove the plume from the air during surgical procedures. Research also supports that compliance with

these recommendations has been inconsistent; thus, exposing the surgical team to a hazard that can cause harm.

The Diffusion of Innovations model by Rogers (2003) describes key indicators that can influence the adoption of an innovation or practice. This model can be used to determine the likelihood of the use of smoke evacuation recommendations by exploring the individual innovativeness characteristics of the perioperative nurse, the nurses' perceptions of the innovation attributes or complexity of the smoke evacuation recommendations, and innovativeness characteristics of the organization where the nurse practices. A thorough review of the literature provides a direction that different indicators may take in influencing compliance with smoke evacuation recommendations. Previous research results that have been highlighted in this chapter offer a foundation upon which the different hypotheses have been formulated.

The next chapter focuses on the research design, population and sampling procedures involved with this study along with an explanation of the data collection tool and survey process used. Data analyses and limitations of the study are also described.

CHAPTER III: METHODOLOGY

This Methods chapter provides a detailed explanation of how this study was conducted. The purpose of the study is to identify key indicators that are associated with different levels of compliance by perioperative nurses with smoke evacuation recommendations. Even though evidence-based recommendations have been published to minimize the hazards associated with inhalation of surgical smoke, these recommendations are not being consistently followed by perioperative nurses as supported by research at Duke (Edwards & Reiman, 2008). The research questions prompted by this problem and patterned after the Diffusion of Innovations model include: What innovativeness characteristics and perceptions of perioperative nurses influence the level of compliance with smoke evacuation recommendations? And what organizational innovativeness characteristics influence the level of compliance with smoke evacuation recommendations? The research design, population and sampling procedures, data collection tool, survey process, data analyses, and limitations of the study are described in more detail in the following sections.

Research Design

A descriptive explanatory and exploratory study using a web-based survey format was conducted involving a systematic investigation of relationships between the independent predictor variables of individual innovativeness characteristics, perceptions

of the smoke evacuation recommendations, and organizational innovativeness characteristics and the dependent variable of the level of compliance with the research-based recommended practices on smoke evacuation practices. The rationale for this research design includes:

1. The explanatory methodology is being used to indicate the relationship between the independent variables and the dependent variable. The explanatory methodology also determines the accuracy of the Diffusion of Innovations model to this situation.
2. The descriptive methodology is used not only to describe the variables in frequencies or averages, but also to describe the relationships between the variables. The descriptive process provides an accurate profile of the perioperative nurse, his or her perceptions of the smoke evacuation recommendations, and the organization. These descriptions provide a basic background or context of the independent variables of this study. Using this methodology also stimulates new thoughts or ideas about how the independent variables relate to the dependent variable.
3. The exploratory methodology attempts to explore areas not yet explored to obtain new insights or determine new relationships between the individual and organizational characteristics that influence compliance with smoke evacuation recommendations. The exploratory methodology also creates a foundation for further research, generates a direction for future research, and develops new

hypotheses about variables influencing compliance with smoke evacuation recommendations.

This research design is very appropriate for this study as the key indicators of compliance with smoke evacuation recommendations need to be determined. This, in turn, will lead to targeted educational activities that create a safer workplace environment for perioperative nurses and other members of the surgical team.

Population and Sampling Procedures

The population for this study is perioperative nurses who are members of the Association of periOperative Registered Nurses (AORN), a professional organization of over 42,000 perioperative nurse members. The inclusion criteria for participation are staff nurses who have e-mail addresses, who work with electrosurgical devices in hospitals or free-standing surgical environments, who speak English and live in the United States, and who volunteer to participate in this study. Exclusion criteria include nurses who do not meet the inclusion criteria or who served as experts in the survey development.

Perioperative nurses were sampled for this study since there must be at least one perioperative nurse involved with every surgical procedure, thus perioperative nurses represent a consistent professional who is present for each surgical procedure. Also staff perioperative nurses have the ability to initiate smoke evacuation practices during the surgical procedure. The AORN membership of perioperative nurses offers easy access to reach the potential research participants. Also previous research indicates that AORN member nurses do not consistently evacuate surgical smoke (Edwards &

Reiman, 2008). AORN members have been very eager in the past to respond to web-based surveys according to the head of the AORN membership department (Tepp, B. personal communication, July, 2008).

An AORN headquarters representative assisted with the process involved with the random sampling of the target population. Automatic computerized simple random sampling method was used that identified every *"nth"* nurse within the AORN membership population who meets the inclusion criteria ((Tepp, B. personal communication, July, 2008)).

A population of AORN staff nurse members who have e-mail addresses includes approximately 20,272 members ((Tepp, B. personal communication, January 9, 2009). A response of 643 nurses is needed to confirm a 99 percent confidence level for this population size. This size of the needed population responding was determined using the Raosoft calculator provided online at the Raosoft website (Raosoft, 2008). The calculator determines sample size of responses needed with the input of the following information: Five percent margin of error expected (or the amount of error tolerated), 99 percent confidence level desired (or the amount of uncertainty accepted), population size of 20,272 (of staff nurses with e-mail addresses), and a response distribution of 50 percent .that would give the largest sample size.

A random sampling totaling 4000 was conducted that represents 19.73 percent of the targeted universe. A random sampling of the first group of 2000 perioperative nurses was conducted on December 8, 2008. Since the survey period was conducted

over the holidays, which most likely impacted the response rate, another random sampling of 2000 perioperative nurses was done on January 2, 2009.

Response rates for nurses responding to surveys have been varied (Li et al., 2004, Ulrich & Grady, 2004). Low response rates are often associated with bias even when the analysis of the non-response bias demonstrates that the sample is representative (Asch et. al., 1997). Many authors and researchers support that there is no correlation between low response rates and bias (Asch et. al., 1997, Halpern & Asch, 2003). Even though reports of response rates by Dillman (2007) comparing mail surveys with internet surveys found that the response rates for both were about 58 percent, lower response rates do not necessarily indicate bias if the responders are similar to the underlying target population (Halpern & Asch, 2003). Dillman (2007) states that multiple contacts are usually effective in increasing responses to surveys so the randomly sampled participants were contacted three times in this study (initial letter of invitation plus two reminders).

Data Collection Tool (Instrumentation)

Question Pro is used as the internet vehicle to offer the survey to the random sampling of perioperative nurses. Question Pro does not record the number of e-mail addresses that have bounced back when the initial e-mail letter of invitation is sent. Even though many e-mail address listings for organizations may be fluid, AORN reports that most of the e-mail addresses of the AORN members are valid (B. Tepp, personal communication, January 17, 2009) and that a problem with the e-mail invitations bouncing back is not a concern.

The survey tool developed for this study follows the format set forth by the Diffusion of Innovations model as illustrated in Appendix B. Modifications of this instrument have been used to survey healthcare professionals in the past to determine the level of innovativeness or adoption of technology or practices (Hooper, 2009, Moore & Benbasat, 1991). Questions on the survey originated from previously conducted surveys already validated along with questions designed specifically for this study. Questions used in past studies were modified with permission from the original researchers. Dr. Baggs gave permission to adapt her survey on Collaboration and Satisfaction about Care Decisions (Baggs & Schmitt, 1997) to note the interconnectedness factor in the organizational characteristics section. Researchers Hebert along with Hooper gave their permission to adapt their questions (Hebert & Benbasat, 1994, Hooper, 2009) designed to address perceptions about the attributes of the practice guidelines.

When the first draft of the survey tool was developed, it was reviewed by five recognized experts in laser and electrosurgical technology who have lectured and written extensively on the topic of surgical smoke hazards. They reviewed the survey using psychometric analyses for the presence of understandable instructions, clear wording, appropriate questions, irrelevant questions, appropriate survey length, and sufficient detail in the survey material. They made suggestions for changes within the tool that were addressed through revising some of the verbiage. Also a statistics consultant, experienced in the creation and pilot testing of surveys, assisted with the development and revision of this survey tool. The revised survey was used as a pilot

test that was conducted at the AORN Congress in Anaheim, California, on March 31, 2008. Twenty-six staff nurses, who work with electrosurgical energy that produces surgical smoke, volunteered to complete the paper survey. Since the pilot testers consisted of perioperative staff nurses, reliability of this survey tool was strengthened since the perioperative staff nurses represent the target population for this study. Analysis of the pilot testing results indicated the need for minor changes in the survey instrument. For example, regrouping the numbers within response categories was done to provide more options for answers to some of the questions. Response ranges to the question asking for years of experience in the OR were changed since approximately 69 percent of the responses in the pilot survey noted over 20 years of experience. More options were added to specifically define the "over 20 years of experience" response. A final version of the survey was created and again reviewed by the five recognized experts (see Appendix C). The newly revised survey was piloted with 23 volunteers during two weeks in August 2008. No major changes were needed to be made as a result of this pilot.

The extent that a survey measures what it purports to measure is known as validity. A survey used in research must be validated so the results can be accurately understood and applied. The validity of a survey cannot be determined through one test or statistic but can be addressed through demonstrating a relationship between the survey questions and the behavior being measured (Van Wagner, n.d.), such as compliance with smoke evacuation recommendations.

Experts in smoke evacuation closely examined the survey for validation. Two types of validity for the survey used in this research include content validity and construct validity. Content validity is addressed as the survey questions were reported by the experts to directly deal with the issue and scope of compliance with smoke evacuation recommendations. The format of the survey questions parallel other studies using the Diffusion of Innovations model that focuses on individual and organizational characteristics that influence compliance or adoption of a practice or technology. Construct validity, as confirmed by the experts, is addressed since the survey constructs are directly related to the theoretical constructs within the Diffusion of Innovations model as illustrated in Appendix B. The survey questions demonstrate an association between the independent variables of individual and organizational characteristics that could influence the dependent variable of compliance with smoke evacuation recommendations.

Face validity also was confirmed by the experts who noted that the survey questions made sense to them and appeared to be appropriate to answer the research questions posed. Assuming there is a relationship between the individual/organizational characteristics with the level of compliance with smoke evacuation recommendations, external validity is then addressed meaning that the study results can be generalized to the population of AORN nurse members across the United States because of the randomization of the sample.

The two pilot studies were analyzed for reliability. For the first pilot study's three independent variable categories, a Cronbach's α was calculated to quantify the

degree that the questions are coherently measuring the underlying attribute they are trying to measure. A rule of thumb states that Cronbach's α values greater than 0.7 indicate that a set of questionnaire items is coherently measuring an underlying construct.

For the first pilot, the measures of perceptions of innovation attributes revealed a Cronbach's alpha α of 0.884 while organization innovativeness resulted in a Cronbach's alpha α of 0.788. The individual innovativeness data were not found to provide a reliable scale so adjustments were made in the survey, adding 5 more questions. The second dataset of pilot responses were again analyzed for reliability. Questions on the pilot survey were grouped into three categories as listed in Table 2.

To calculate Cronbach's α for a group of items, the scales of the items must be oriented in the same direction. For example, with the first construct, the "higher" end of the scale must always indicate more individual innovativeness. In the original database for the first pilot survey, the coding was not always in the same direction for variables in the same group. For example, increasing education is expected to be associated with higher individual innovativeness, and CNOR certification of "Yes" (coded as 1 for "Yes" and 2 for "No") is also expected to be associated with higher individual innovativeness. As a result, the CNOR certification variable had to be recoded so that "Yes" was associated with the higher value. This type of reverse coding was performed for some of the other elements within the variables. In addition, education was recoded so that AD in Nursing was the lowest level, Diploma in Nursing was the next highest,

Table 2. Independent Variables within the Three Construct Categories

1. Individual Innovativeness	**2. Perceptions of Innovation Attributes**	**3.Organization Innovativeness**
Age	All questions of perceived smoke evacuation attributes, beginning with "Complying with smoke evacuation recommendations enables me to provide care more efficiently" through "Overall, I believe that smoke evacuation recommendations are easy to follow."	Locale (urban or rural)
Education level	Noise as a barrier	Magnet status
Years of experience	Reliability as a barrier	Number of OR's
Number of educational sessions attended	Inconvenience as a barrier	Number of cases
Number of professional articles read	Cost as a barrier	Different specialties offered
CNOR certification		Number of management levels above staff
CRNFA certification		Number of management levels above Director
Formal training in smoke evacuation		Interconnectedness questions
Presence of allergies, asthma, emphysema-like conditions, breathing difficulty, increased coughing, increased nose bleed, nasal congestion, sinus infection, nasal polyps, bronchitis.		Questions of leadership support
Smoking status		Physicians as a barrier
Self rating as a change agent		Equipment availability as a barrier
Self rating as having control over own future		OR Director as a barrier
Self rating as venturesome		Complacency of staff as a barrier

BSN and BS/BA other field were tied at the next highest level, MSN and MS/MA other field were tied at the next highest level, and PhD/EdD/Practice doctorate was the highest level.

For the individual innovativeness category, some of the variables that were intended to inform about individual innovativeness could not be included in the calculation of Cronbach's α because all respondents to the pilot survey answered exactly the same way. These variables included presence of emphysema-like conditions (all answered "No"), Presence of Breathing Difficulty (all answered "No"), Presence of Increased Nose Bleed (all answered "No"), and Smoking Status (all answered "No"). After these variables were removed, the first reliability calculation a Cronbach's alpha value was 0.046. Further investigation indicated that while age and years of experience were positively correlated with each other, they were negatively correlated with the three main measures of innovativeness (Change Agent, Control of Future, and Venturesome). Therefore, age and experience were removed in the calculation of reliability for the scale of individual innovativeness.

Recalculating the reliability without these two measures produced a Cronbach's α of 0.618. While this value is good, it still does not reach the 0.7 rule of thumb. Next, the dichotomous variables were removed from the analysis, including all of the respiratory conditions and smoking status. In such a small sample, it is possible that these dichotomous variables are not providing a good measure of the true correlations within the sample. Removing these variables, Cronbach's α increases to 0.657.

Examining the remaining variables and performing exploratory analysis, it appears that the questions related to training are the most problematic. To increase the Cronbach's α value further, the questions about educational sessions attended, articles read, and smoke evacuation training were removed. The following variables remained:

- Education Level
- CNOR Certification
- CRNFA Certification
- Self Rating as a Change Agent
- Self rating as Having Control Over Own Future
- Self Rating as Venturesome

With these six variables, we obtain a Cronbach's α level of 0.750. For the second pilot, only these six variables are used as indicators of the level of an individual's innovativeness. In the final actual study, the other variables were added and removed in the calculations to determine significance that is explained in more detail in Chapter IV.

For the variables within the category of perception of innovation attributes, the Cronbach's α was 0.869. No variables were removed from the analysis. This value of α indicates that the questions used are coherently measuring perception of innovation attributes.

For all variables related to organizational innovation, the Cronbach's α was 0.838. No variables were removed from the analysis. This value of α indicates that the questions used are coherently measuring organizational innovativeness characteristics.

The results from the two pilot surveys note that the average time involved with completing the survey is approximately 15 minutes. This information was used in the e-mail inviting the random sample of perioperative nurses to participate in this study.

Survey Process

The survey was placed online with the assistance from a liaison at the AORN headquarters. The most successful format for AORN web-based surveys has been Question Pro, which allows the participant to move from one question to the next with great ease with any type of home or business computer hardware (Tepp, B. personal communication, July, 2008). Explanations to help the participant navigate easily through the survey were provided. Concerns about using a web-based survey have been addressed by the AORN liaison who has years of experience with this type of survey (Tepp, B. personal communication, July, 2008). Issues such as sample size, response rate, procedures involved with random sampling, and other questions were discussed so that any concerns were addressed proactively.

Invitation Letter to Participate in the Study

When the potential nurse participants were identified by a random sampling of 2000, a letter of invitation to participate in the study was sent by e-mail on December 8, 2008 (Appendix D). Any returned or inaccurate e-mail addresses were not followed up for correction. The initial letter of invitation that was sent via e-mail is worded to encourage participation by the sampled nurses. The invitation letter includes a number of valuable details to inform the potential participant of the importance of this ground-breaking study, which is designed to determine key indicators that influence compliance with smoke evacuation recommendations. The letter states that this information will then be used to design educational programs that will promote compliance and lead to a safe workplace environment. The letter also states that the participant has been chosen

because of his or her membership in AORN and role as a staff nurse during surgical procedures involving the generation of electrosurgical smoke. The fact that AORN and Virginia Commonwealth University's Institutional Review Board approved the study is also highlighted. The letter describes that the participants' identifying information (name and address) will be separated from the survey responses so that confidentiality can be maintained. Also the participate is informed that if responding to any question is uncomfortable, then the response area can be left blank. Also mentioned is that that no foreseeable risks of participating in this survey are contemplated and any participant can withdraw at any time while completing the survey. The letter states that an incentive of a $10 gift certificate to the AORN online bookstore is offered to the first 650 participants who complete the survey. Finally the letter also announces that the study results will be disseminated at the 2009 AORN Congress and through an article submitted for publication in the *AORN Journal*.

When a perioperative nurse agrees to participate, a highlighted web address linked the participant to the web survey site. A reminder letter was e-mailed on December 22, 2008 (Appendix E) with a second reminder sent on December 30, 2008 (Appendix F).

Since the survey was conducted during the holiday season and a low response rate was anticipated, a second random sampling of 2000 perioperative nurse members received a letter of invitation on January 2, 2009. A reminder e-mail letter was sent to this second sampling on January 9, 2009 and again on January 16, 2009.

The actual survey period lasted from December 8, 2008 until January 30, 2009, which was similar to other studies that targeted surgical team members to respond to a survey (Edwards & Reiman, 2008, Hooper, 2009). Participants were thanked at the end of the survey for their participation and were given the option to provide their name and address to receive the $10 gift certificate to the AORN online bookstore as a small token of appreciation for their involvement. After the survey was closed, the gift certificate and letter (Appendix G) were sent to those who chose to receive the optional gift certificate.

Data Collection Procedure

The responses received from the web-based survey were automatically tallied as they were received on an Excel spreadsheet and then translated and stored in specific SPSS databases depending on the survey question topic and response categories. At the end of the survey period, the AORN representative gathered the names of those who completed the survey and then sent the token $10 gift certificate via postal mail service to those participants accepting the offer. When the results of the data collection were sent to the researcher, no identifying information was included about the participant. Data collection extended from December 8, 2008 to January 30, 2009.

Data Analysis

The survey was formatted in Question Pro with the responses being tallied using Excel software. These data were then transferred to the statistical package SPSS for analyses. Statistical analyses of the data involves two stages that offer descriptive statistical measures and explore how the independent variables relate to the dependent

variable. The dependent variable is the level of compliance with smoke evacuation practices. The dependent variable is expressed using eight different surgical procedures including mastectomy, total hip replacement, tonsillectomy, vaporization of condyloma, hemorrhoidectomy, laparoscopic dissection, microlaryngoscopy with removal of vocal cord polyp, and colonoscopy with three different smoke evacuation options, including the use of a smoke evacuator, suction line with inline filter, and suction line only. The participant is asked how often each smoke evacuation method is employed for each procedure using the ranges of always for 100 percent of the time, often for 50-99 percent of the time, sometimes for less than 50 percent of the time, and never for not at all. The option of N/A (not applicable) is also offered as a response choice if the nurse is not involved with a specific surgery.

Since the variables were clearly identified and defined, relationships can easily be recognized. These analyses, in turn, determine if the following hypotheses are supported:

Hypotheses regarding the independent variable of the individual innovativeness characteristics of the perioperative nurse include:

H1. **As the ages of perioperative nurses increase, compliance with surgical smoke evacuation recommendations decreases.**

H2. **As the number of years of formal education for perioperative nurses increase, compliance with surgical smoke evacuation recommendations increases.**

H3. **When the amount of experience, knowledge, and training regarding surgical smoke evacuation increases, compliance with surgical smoke evacuation recommendations increases.**

H4. **When the incidence of reported respiratory problems by perioperative nurses increases, compliance with surgical smoke evacuation recommendations increases.**

Hypotheses regarding the independent variable of the nurses' perceptions of the attributes of smoke evacuation recommendations include:

H5. **When the perceptions of perioperative nurses are favorable regarding the attributes of relative advantage, compatibility, and observability of smoke evacuation recommendations, compliance with smoke evacuation recommendations increases.**

H6. **When perioperative nurses perceive the smoke evacuation recommendations as being complex, then compliance with smoke evacuation recommendations will be low.**

H7. **The higher the nurses rate specific barriers (as an obstacle to complying with smoke evacuation recommendations), the more likely the nurses are not going to comply with smoke evacuation recommendations.**

Hypotheses regarding the independent variable of the organization's innovativeness characteristics include:

H8. **When organizations are large in size, compliance with smoke evacuation recommendations increases.**

H9. **When organizations exhibit greater complexity, compliance with smoke evacuation recommendations increases.**

H10. **When organizations exhibit greater interconnectedness, compliance with smoke evacuation recommendations increases.**

H11. **When organizations show leadership support, compliance with smoke evacuation recommendations increases.**

H12. **When organizations have a high level of formalization, then compliance with smoke evacuation recommendations will be low.**

H13. **The higher the nurses rate specific organizational barriers (as an obstacle to complying with smoke evacuation recommendations), the more likely the nurses are not going to comply with smoke evacuation recommendations.**

In the first stage of the analyses, descriptive statistical measures are analyzed to understand variation in both the independent variables (characteristics of nurses, perceptions of nurses, and characteristics of organizations) and the dependent variable (the measure of how frequently each smoke evacuation method is used for specific procedures). Examination of the descriptive statistics and creation of graphs summarizing the data provide useful insight for more complex analyses.

In the second stage, each component of the different independent variables are related to the dependent variable using bivariate analysis techniques. The techniques used to analyze the data are a combination of two-sample t-tests (when the independent variable only had two levels, such as "Magnet Status"), regressions (when the independent variable was continuous, such as "Age"), and one-way analyses of variance

or ANOVA (when the independent variable had more than two levels and could not be considered continuous). The results are exploratory as this produced a large number of analyses in addressing each hypothesis. By examining these relationships, some preliminary insight into the ways that the variables interact with each other is also demonstrated. Smoking was applied as a covariate to see if it was significant. Post-hoc analyses using Tukey tests are often performed after the analyses to find patterns within the subgroups that are not specified a priori (previous knowledge about the groups). These tests are done so that the outcomes are not misleading.

Limitations

The response rate is dependent upon the willingness of the perioperative nurses to participate in the study. Since the study began during the holiday season, a low response rate was expected so another random sampling of 2000 was done again in January. The response rate may be influenced by offering the $10 gift certificate incentive. Also the compelling words used in the invitation letter may encourage nurses to participate knowing their responses ultimately will help ensure a safe workplace environment.

Internal validity of the research design addresses the extent to which the independent variables are truly influencing the dependent variable. A threat to internal validity for this study includes history. Since the hazards of surgical smoke have become such a recognized topic of discussion, lectures and publications with information about the need to evacuate surgical smoke may have caused participants to answer according to what they think they should be doing instead of what actually is

being done to evacuate surgical smoke, thus possibly skewing the results. Expectancy effects can be a threat to external validity too. The participants were aware of their participation in the survey and may have falsely responded to the smoke evacuation compliance statements as they want to reflect best practices regarding smoke evacuation. In an attempt to avoid these biases, the survey questions were worded in such a way to avoid false answers while the instructions were fashioned to highlight confidentiality and the importance of truthful answers.

The requirement of AORN membership for participation may have produced a nonequivalent group of perioperative nurses who are more apt to evacuate surgical smoke since they receive information about workplace hazards as a benefit of AORN membership. This could have been handled by extending the survey to nonmembers for their responses. However, the Duke study supports a significant lack of smoke evacuation practices within the AORN nurse membership (Edwards & Reiman, 2008).

External validity of the research design addresses the ability to generalize the findings to a larger population. A threat to external validity for this study includes a systematic bias in the selection of subjects to participate in the study. Since a random sample of only staff nurses with e-mail addresses who are willing to participate was used, this sample may not reflect the general population of perioperative nursing practices involved with smoke evacuation. To correct for this threat, some of the demographic independent variables are compared with AORN universe database variables to see if they actually mirror each other. For example, AORN database results of average age and education level are compared with the responses from the

participants in the study to see if they matched so that generalizability can be determined.

Summary

The methods used for this study reflected the most appropriate processes needed to determine the key indicators of innovativeness characteristics that influence compliance with smoke evacuation recommendations. A previous study by Hooper effectively followed this format to determine the differences in responses by various healthcare providers in complying with evidence-based practice guidelines (Hooper, 2009). Using a detailed two step process for analyses provides a thorough evaluation of the results so that significance can be revealed that will guide future research and will offer valuable information to create meaningful educational programs to ensure compliance with smoke evacuation recommendations. The next chapter will report the results of the survey responses including reliability analysis, determination of smoking as a co-variant, descriptive statistics, and hypotheses testing.

CHAPTER IV: RESULTS

As stated in Chapter I, this study was conducted to determine the key indicators that are associated with compliance with surgical smoke evacuation recommendations by perioperative nurses. This chapter begins with a reliability analysis to determine if the variables are internally consistent and to compare the participants with the universe of AORN staff nurses. Major findings are discussed and compared with previous research. Smoking is explored as a possible co-variant in analyzing the data followed by an overview of the demographic description of the participants in the study. The rest of the chapter is organized based on the three specific research questions (including the hypotheses) posed in Chapter I that include the perioperative nurses' innovativeness characteristics, their perceptions of the attributes of the smoke evacuation recommendations, and the organizations' innovativeness characteristics as related to the influence on the level of compliance with surgical smoke evacuation recommendations.

Reliability Analyses

An analysis was performed to determine the consistency among the correlations for the independent variables. Reliability scores are high for all three constructs including individual innovativeness, perception of the smoke evacuation recommendation attributes, and organizational innovativeness. For each construct, Cronbach's α was calculated; Cronbach's α scores over 0.7 are conventionally assumed

to indicate a coherent scale. The variables and resulting scores are illustrated in Table 3. The variables with "Recode" on the end are the reverse coded variables to align all of the variables in the same direction so correlation significance can be determined.

Table 3. Cronbach's α Analysis for the Different Constructs

Construct	Variables Used	Cronbach's α
Individual Innovativeness	ChangeAgent ControlFuture Venturesom TrainingRecode*	0.733
Perception	CareEfficiently ImprovesQuality EaseofCare EnhanceEffectiveness Control Compatible FitsPractice WorkStyle Understandable ImplementEasy EasyToFollow NoiseRecode ReliabilityRecode InconvenienceRecode CostRecode	0.867
Organizational Innovativeness	Locale Magnet ORs Cases Bariat Cardiothor DentalOral ENT GI General GYN Neuro Ophthal Ortho Peds Plastics Oncol Transplant Trauma Uro MgtAboveStaff MgtAboveDir SupportAORNRPs SupportAORNSmoke SupportORpol SupportDrs PlanDrRN OpenComm DecMake Cooperate RNDrConcerns Coordination Collaboration Satisfaction PhysiciansRecode AvailEquipRecode ORDirectorRecode ComplacencyRecode	0.775

*Several other variables, including age, education, and various symptoms were considered for this construct. However, they all reduced the alpha value and were consequently removed.

Because these three scales are found to be internally consistent, the variables corresponding to each one are combined into a single score. To ensure that each question carried equal weight a process was performed to guarantee that. The center of the scale was subtracted from each variable and the result was divided by half the length of the scale before averaging. For example, the "ChangeAgent" variable is measured on a 1 -10 scale, so it would be transformed using the following formula: ChgAgNew =

(ChangeAgent – 5.5) / 4.5. As a result, each individual modified variable was converted to a scale from -1 to +1. The mean of the transformed values was then used as the final measure. Descriptive summaries of these new variables are presented in Table 4.

Table 4. Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Ind. Innovativeness	796	-1.00	1.00	.2755	.42154
Perception	784	-1.00	1.00	.3060	.36568
Org. Innovativeness	795	-.70	.50	-.2852	.20203
Valid N (listwise)	784				

A comparison with the AORN universe helps to note if the study results are generalizable to a larger population of AORN members. Three different states are selected to compare the percentage of responses as examples of representation. Listed in Table 5 are the comparisons between the study and AORN membership.

Table 5. Comparison of Study Participants to AORN Membership

Characteristic	Study results	AORN membership
Age	51.01	47.00
Associate Degree in Nursing	25.44%	25.95%
Diploma in Nursing	18.01%	17.46%
Bachelors Degree	46.98%	43.60%
Masters Degree in Nursing	3.78%	5.90%
State of employment	All states represented	All states represented
Ohio representation	3.90%	4.25%
Georgia representation	2.90%	2.43%
MA representation	2.20%	2.65%

Data Exploration and Smoking Status Evaluation

Each of the independent variables are checked against smoking status using either t-tests (if the variable being compared to smoking was on a continuous scale) or chi-squared tests (if the variable being compared to smoking was categorical or on a very short ordinal scale). The significant findings are as follows:

- Score for the use of an inline filter during total hip replacement is significantly higher for smokers than non-smokers ($p = 0.039$) with smokers scoring 0.301 points higher on average.
- Smokers have a higher prevalence of emphysema ($p = 0.002$). Prevalence for smokers is 6.8 percent while prevalence for non-smokers was 1.1 percent.
- Smokers have a higher prevalence of bronchitis ($p = 0.037$). Prevalence for smokers is 17.8 percent while prevalence for non-smokers was 8.6 percent.
- There is a marginally significant relationship between smoking status and presence of a pediatric specialty ($p = 0.051$). Smokers are less likely to work in a facility that offers this specialty (47.2 percent vs. 63.4 percent for non-smokers).
- There is a marginally significant relationship between years of experience and smoking status ($p = 0.054$). In general, individuals with more experience are less likely to be smokers.
- Support for AORN recommended practices is significantly different between non-smokers and smokers ($p = 0.021$). Non-smokers answer "always" more often and smokers answer "never" more often.

- Support for AORN recommended practices is significantly different between non-smokers and smokers ($p = 0.021$). Non-smokers answer "always" more often and smokers answer "never" more often.

Because there are only a few differences between the groups and none of these differences are on elements of individual innovativeness, perception, or organizational innovativeness, it was decided that all individuals would be analyzed together and that smoking would not be handled as a co-variant.

Survey and Demographic Descriptions

The survey period was from December 8, 2008 until January 30, 2009 with 4000 randomly sampled perioperative nurses. The survey was viewed by 1043 perioperative nurses, while 800 nurses started the survey and 777 actually completed the survey representing a 97.12 percent completion rate. With 777 participants fully completing the survey, a response rate of 19.4 percent is reflected. With 800 nurses starting the survey (some may not have answered all questions), a response rate of 20.0 percent is reflected. There were 23 nurses who dropped out after starting the survey. The average time taken to complete the survey was 12 minutes.

The average age of the perioperative nurse participant is 51.01 with 725 nurses responding to this question. The ages range from 20 years old to 72 years old. Approximately 75.42 percent of the responders are CNOR (Certified Nurse in the Operating Room) and 0.56 percent are CRNFA (Certified Registered Nurse First Assistant). Participants represent every state in the United States. Approximately 94 percent are nonsmokers while approximately 34 percent had smoked in the past.

Frequencies and Hypothesis Testing

In each of the following subsections, the analyses performed are summarized, and all significant relationships are reported in bullet points for each hypothesis. Also, at the end of each hypothesis subsection the results are summarized and then addressed in more detail in Chapter V. Frequencies are reported if they are significant or noteworthy. When frequencies of the dependent variables are reviewed alone, the following data in Table 6 are reported for the highest percentages of the use of the smoke evacuator, inline filter on a suction line, and suction line only for each of the eight surgical procedures considered in the survey.

Table 6. Frequency Percentages of Smoke Evacuation Method Use

Procedure	**Smoke evacuator**	**Inline filter**	**Suction only**
Mastectomy	49% Never	55% Never	29% Always
Total hip replacement	69% Never	56% Never	31% Always
Tonsillectomy	69% Never	60% Never	40% Always
Condyloma vaporization	54% Always	45% Never	40% Never
Hemorrhoidectomy	64% Never	59% Never	37% Always
Laparoscopic dissection	62% Never	54% Never	32% Always
Microlaryngoscopy	50% Never	48% Never	31% Always
Colonoscopy	44% Never	40% Never	24% Always

In the bivariate analyses for hypothesis testing, higher scores for the use of the smoke evacuator or suction with the inline filter indicate more appropriate implementation of smoke evacuation recommendations. Depending on the surgical procedure, the most appropriate method of smoke evacuation is coded the highest. For example, during mastectomy procedures, the most efficient method of evacuation is using the smoke evacuator. Using an inline filter on the suction line is the next best.

Suction only is reverse coded because it is not an appropriate smoke evacuation practice. If the participant responds with the Never response to a specific smoke evacuation practice, then that type of practice is never used. For example responding with "Never" for "Mastectomy – smoke evacuator" would indicate an undesirable response that a smoke evacuator is never used while responding with "Never" for "Mastectomy – suction only" would be a desirable response in that a suction only device is never used. Again higher scores are always better since they reflect the most appropriate smoke evacuation method. Table 7 illustrates the coding scheme for mastectomy.

Table 7. Coding Scheme for Mastectomy

Dependent Variable	"Always" coding	"Often" Coding	"Sometimes" Coding	"Never" Coding
Mastectomy – smoke evacuator	4	3	2	1
Mastectomy – inline filter	3	4	2	1
Mastectomy – suction only	1	2	3	4

The following sections address each hypothesis within the three different segments of the Roger's model which include individual innovativeness characteristics, perceptions of the smoke evacuation recommendation attributes, and organizational innovativeness characteristics. Frequencies are sometimes included if they are significant, remarkable, or unanticipated. Figures are used to help illustrate the findings.

Individual Innovativeness Characteristics

Each individual hypothesis is addressed in this section for individual innovativeness characteristics.

H1. **As the ages of perioperative nurses increase, compliance with surgical smoke evacuation recommendations decreases.**

The only significant finding is:

- Older individuals score lower for "tonsillectomy - suction only" ($p = 0.026$).

The "suction only" option is reverse coded so that this smoke evacuation option would be rated lower meaning that "always" is coded lower and "never" is coded higher. Refer to Table 7 for the example of the coding scheme. The older nurses tend to use "suction only" more often during tonsillectomy procedures. The use of suction only is not an effective smoke evacuation method; therefore the coding is lower. Since only one significant finding is revealed in the analysis, overall conclusions note that age does not appear to be strongly related to whether surgical smoke evacuation recommendations are implemented.

H2. **As the number of years of formal education for perioperative nurses increase, compliance with surgical smoke evacuation recommendations increases.**

Analysis of the frequency of education levels reveals that the most common education level of those responding is the Bachelor's Degree as reflected in Figure 1 with over 40 percent of the nurses having a Bachelor's Degree in Nursing and over 6.3 percent having a Bachelor's Degree in another field of study.

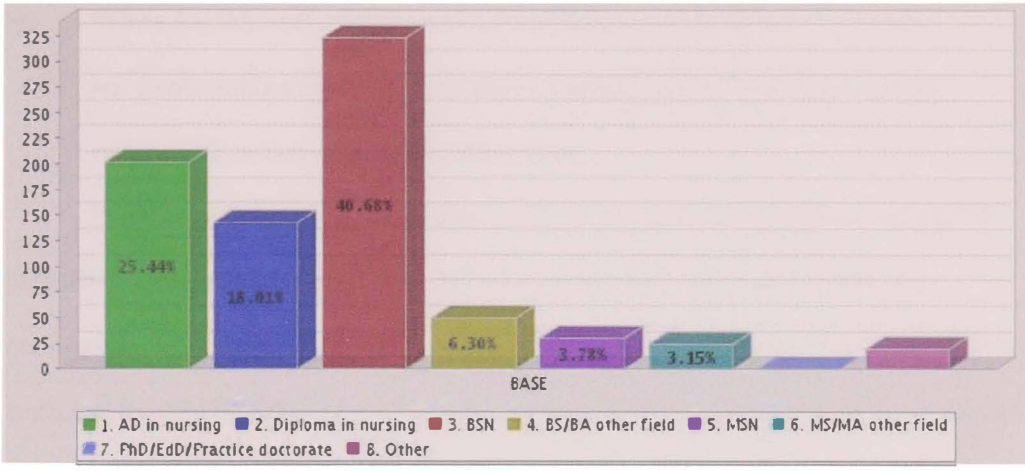

Figure 1. Highest Level of Education Achieved

For the bivariate analysis, the highest group (PhD) is removed since only one Ph.D. responded to the survey. One-way ANOVA is used to assess relationships. The following reports the significant findings.

- Education is marginally significant for "mastectomy – inline filter" ($p = 0.051$). Post-hoc Tukey tests find no significant differences between educational groups. Post-hoc Tukey tests are performed to determine if there is a significant difference between the groups.
- Education is significant for "total hip replacement – inline filter" ($p = 0.027$). Post-hoc Tukey tests find that MS/MA Other field had a significantly lower score than MSN for this method with this procedure.

An overall conclusion notes that the difference in educational levels achieved does not appear to be strongly related to compliance with surgical smoke evacuation recommendations.

H3. **When the amount of experience, knowledge, and training regarding surgical smoke evacuation increases, compliance with surgical smoke evacuation recommendations increases.**

For this hypothesis, the following variables are tested (methods are reported in parentheses for each): Experience (ANOVA), educational offerings (ANOVA), readings (ANOVA), CNOR (t-test), CRNFA (t-test), training (t-test), ReadAORNRP (t-test), and ReadAORNPS (t-test). For educational offerings, there are only three people who reported more than 10, so these people are combined to make a "more than 10" group.

Figure 2 reports the frequencies associated with years of experience in the operating room noting that almost 70 percent of the participants have over 16 years of experience. Bivariate analysis does not reveal any significant findings to indicate that more experience in the operating room influences the implementation of smoke evacuation practices.

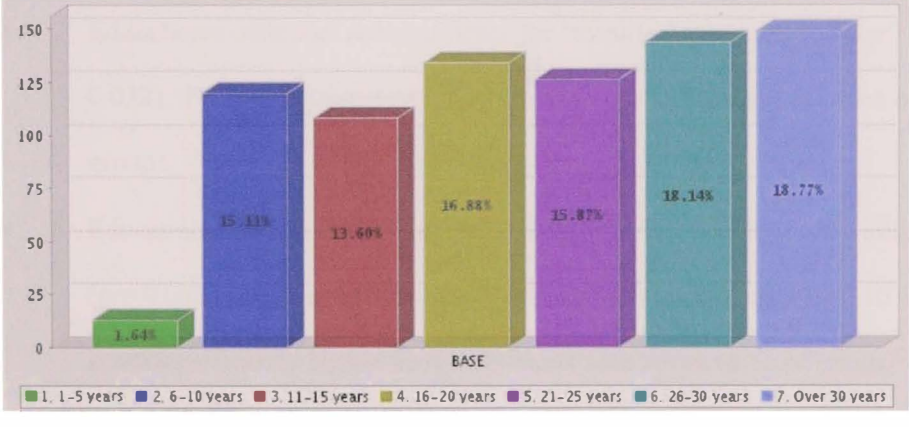

Figure 2. Years of Experience in the Operating Room

Significant findings are listed below for the question regarding the number of educational offerings attended within the past five years regarding smoke evacuation.

- Educational offerings are significant for "mastectomy – smoke evacuator" ($p < 0.001$). Post-hoc Tukey tests find individuals with more than 10 offerings scored significantly higher than all other groups.
- Educational offerings are significant for "mastectomy – inline filter" ($p = 0.012$). Post-hoc Tukey tests find no significant differences between educational groups.
- Educational offerings are significant for "total hip replacement – smoke evacuator" ($p < 0.001$). Post-hoc Tukey tests are not possible due to small numbers of people in the "over 10" group.
- Educational offerings are significant for "tonsillectomy – smoke evacuator" ($p = 0.031$). Post-hoc Tukey tests find no significant differences between educational groups.
- Educational offerings are significant for "tonsillectomy – inline filter" ($p = 0.032$). Post-hoc Tukey tests find no significant differences between educational groups.
- Educational offerings are marginally significant for "condyloma – inline filter" ($p = 0.052$). Post-hoc Tukey tests find individuals with more than 10 offerings score significantly higher than individuals with seven to 10 offerings.
- Educational offerings are significant for "hemorrhoidectomy – smoke evacuator" ($p < 0.001$). Post-hoc Tukey tests find individuals with more than 10

offerings score significantly higher than individuals with fewer than seven offerings.

- Educational offerings are significant for "hemorrhoidectomy – inline filter" ($p = 0.038$). Post-hoc Tukey tests find no significant differences between educational groups.
- Educational offerings are significant for "laparoscopic lysis – smoke evacuator" ($p = 0.006$). Post-hoc Tukey tests find individuals with more than 10 offerings score significantly higher than individuals with fewer than seven offerings.
- Educational offerings are significant for "microlaryngoscopy – smoke evacuator" ($p = 0.040$). Post-hoc Tukey tests find individuals with more than 10 offerings score significantly higher than individuals with fewer than four offerings.
- Educational offerings are significant for "colonoscopy – smoke evacuator" ($p = 0.006$). Post-hoc Tukey tests find individuals with more than 10 offerings score significantly higher than all other groups.
- Educational offerings are significant for "colonoscopy – inline filter" ($p = 0.007$). Post-hoc Tukey tests find individuals with more than 10 offerings score significantly higher than all other groups except for those who had four to six offerings.
- Readings are significant for "mastectomy – smoke evacuator" ($p = 0.003$). Post-hoc Tukey tests find individuals with 11 – 15 readings score significantly higher than individuals with fewer than seven readings.

- Readings are significant for "mastectomy – inline filter" ($p = 0.048$). Post-hoc Tukey tests find no significant differences between reading groups.
- Readings are significant for "laparoscopic lysis – smoke evacuator" ($p = 0.032$). Post-hoc Tukey tests find individuals with more than 15 readings score significantly higher than individuals with fewer than 11 readings.

Certification is explored to determine significance in influencing smoke evacuation practices. The following relationships are found.

- There is a significant relationship between CNOR certification and "mastectomy – smoke evacuator" ($p = 0.030$). Individuals with certification score 0.211 higher on average as compared to those without certification.
- There is a significant relationship between CRNFA certification and "laparoscopic lysis – smoke evacuator" ($p < 0.001$). Individuals with certification score 1.286 higher on average than those without certification.
- There is a significant relationship between CRNFA certification and "laparoscopic lysis – smoke evacuator" ($p = 0.002$). Individuals with certification score 1.221 higher on average than those without certification.
- There is a significant relationship between CRNFA certification and "colonoscopy – smoke evacuator" ($p = 0.014$). Individuals with certification score 0.847 higher on average than those without certification.

The question asking if the perioperative nurse received formal training specifically on the use of smoke evacuation equipment and devices is explored to

determine the significance of the influence on the implementation of smoke evacuation practices.

- Training has a significant impact on many measures: "mastectomy – smoke evacuator" ($p = 0.001$, trained are 0.273 higher), "mastectomy – inline filter" ($p < 0.001$, trained are 0.297 higher), "total hip replacement – smoke evacuator" ($p = 0.001$, trained are 0.186 higher), "total hip replacement – inline filter" ($p = 0.002$, trained are 0.205 higher), "tonsillectomy – smoke evacuator" ($p = 0.011$, trained are 0.130 higher), "tonsillectomy – inline filter" ($p = 0.002$, trained are 0.233 higher), "condyloma – smoke evacuator" ($p < 0.001$, trained are 0.351 higher), "hemorrhoidectomy – smoke evacuator" ($p < 0.001$, trained are 0.245 higher), "hemorrhoidectomy – inline filter" ($p = 0.008$, trained are 0.197 higher) "laparoscopic lysis – smoke evacuator" ($p = 0.001$, trained are 0.222 higher), "laparoscopic lysis – inline filter" ($p = 0.002$, trained are 0.253 higher), "laparoscopic lysis – suction only" ($p = 0.020$, trained are 0.234 **lower**), "microlaryngoscopy – smoke evacuator" ($p = 0.020$, trained are 0.201 higher), "microlaryngoscopy – inline filter" ($p = 0.022$, trained are 0.205 higher), "colonoscopy – smoke evacuator" ($p < 0.001$, trained are 0.233 higher), and "colonoscopy – inline filter" ($p < 0.001$, trained are 0.375 higher).

The following reflect the findings regarding the relationship between reading AORN's recommended practices addressing surgical smoke evacuation (Reading AORNRP) and reading AORN's Position Statement on Surgical Smoke and

Bioaerosols (Reading AORNPS) on compliance with smoke evacuation recommendations.

- Reading AORNRP has a significant impact on "mastectomy – smoke evacuator" ($p = 0.006$). Individuals who answer "yes" score 0.250 higher on average.
- Reading AORNRP has a significant impact on "mastectomy – inline filter" ($p = 0.045$). Individuals who answer "yes" score 0.171 higher on average.
- Reading AORNRP has a significant impact on "total hip replacement – inline filter" ($p = 0.040$). Individuals who answer "yes" score 0.153 higher on average.
- Reading AORNRP has a significant impact on "condyloma – smoke evacuator" ($p = 0.025$). Individuals who answer "yes" score 0.227 higher on average.
- Reading AORNRP has a marginally significant impact on "hemorrhoidectomy – smoke evacuator" ($p = 0.058$). Individuals who answer "yes" score 0.132 higher on average.
- Reading AORNRP has a significant impact on "microlaryngoscopy – smoke evacuator" ($p = 0.033$). Individuals who answer "yes" score 0.210 higher on average.
- Reading AORNRP has a significant impact on "microlaryngoscopy – inline filter" ($p = 0.007$). Individuals who answer "yes" score 0.274 higher on average.

- Reading AORNRP has a significant impact on "colonoscopy – smoke evacuator" ($p = 0.043$). Individuals who answer "yes" score 0.144 higher on average.
- Reading AORNPS has a significant impact on "mastectomy – smoke evacuator" ($p < 0.001$). Individuals who answer "yes" score 0.313 higher on average.
- Reading AORNPS has a significant impact on "mastectomy – inline filter" ($p = 0.012$). Individuals who answer "yes" score 0.203 higher on average.
- Reading AORNPS has a significant impact on "total hip replacement – smoke evacuator" ($p = 0.014$). Individuals who answer "yes" score 0.148 higher on average.
- Reading AORNPS has a significant impact on "total hip replacement – inline filter" ($p = 0.041$). Individuals who answer "yes" score 0.141 higher on average.
- Reading AORNPS has a significant impact on "tonsillectomy – inline filter" ($p < 0.001$). Individuals who answer "yes" score 0.292 higher on average.
- Reading AORNPS has a significant impact on "condyloma – inline filter" ($p = 0.020$). Individuals who answer "yes" score 0.218 higher on average.
- Reading AORNPS has a significant impact on "hemorrhoidectomy – smoke evacuator" ($p = 0.008$). Individuals who answer "yes" score 0.171 higher on average.

- Reading AORNPS has a significant impact on "hemorrhoidectomy – inline filter" ($p = 0.012$). Individuals who answer "yes" score 0.200 higher on average.
- Reading AORNPS has a significant impact on "laparoscopic lysis – inline filter" ($p = 0.004$). Individuals who answer "yes" score 0.258 higher on average.
- Reading AORNPS has a significant impact on "microlaryngoscopy – smoke evacuator" ($p = 0.009$). Individuals who answer "yes" score 0.237 higher on average.
- Reading AORNPS has a significant impact on "microlaryngoscopy – inline filter" ($p = 0.003$). Individuals who answer "yes" score 0.281 higher on average.
- Reading AORNPS has a significant impact on "colonoscopy – smoke evacuator" ($p = 0.028$). Individuals who answer "yes" score 0.141 higher on average.

The overall conclusion from this data is that increased educational offerings, increased training, and increased reading of AORN materials on smoke evacuation appear to be strongly related to compliance with surgical smoke evacuation recommendations.

H4. **When the incidence of reported respiratory problems by perioperative nurses increases, compliance with surgical smoke evacuation recommendations increases.**

Figure 3 displays the frequency of responses with the higher numbers indicating the "no" response and the lower numbers indicating the "yes" response (1 = yes, 2 = no). The most frequently reported respiratory symptoms are nasal congestion (32.82 percent), increased coughing (24.74 percent), allergies (24.23 percent), and sinus infections or problems (22.93 percent). Other conditions reported by the nurses are asthma (10.87 percent) and bronchitis (9.04 percent).

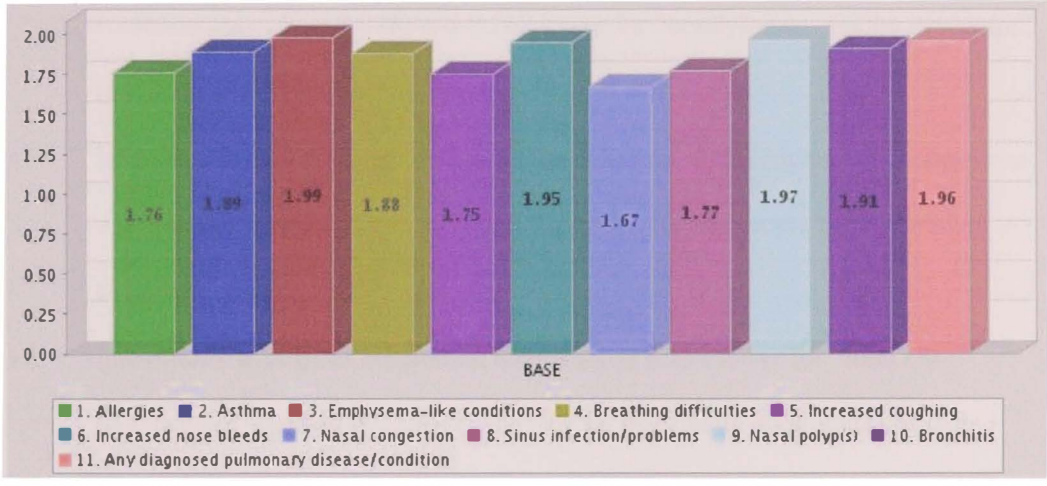

Figure 3. Respiratory Problems Possibly Linked to Surgical Smoke Inhalation

For the testing of this hypothesis, two-sample t-tests are used to test each symptom against smoke evacuation strategies. In addition, the number of "yes" answers to symptom questions are summed to get a total number of symptom categories, and this number is regressed against each strategy. The following significant findings are revealed.

- Individuals with allergies have a score 0.196 lower for "tonsillectomy – inline filter" ($p = 0.002$) (the interpretation for this is that people with allergies score

0.196 lower, so they are using the inline filter less for tonsillectomy procedures than people without allergies), 0.176 lower for "hemorrhoidectomy – inline filter" ($p = 0.046$), and 0.256 lower for "colonoscopy – inline filter."

- Individuals with asthma have a score 0.203 lower for "colonoscopy – smoke evacuator ($p = 0.054$, marginally significant).
- Individuals with breathing difficulty have a score 0.238 higher for "mastectomy – suction only" ($p = 0.048$) and 0.267 lower for "condyloma – smoke evacuator" ($p = 0.056$, marginally significant).
- Individuals with increased nose bleed have a score 0.456 higher for "condyloma – inline filter" ($p = 0.026$) and 0.383 higher for "laparoscopic lysis – smoke evacuator" ($p = 0.020$).
- Individuals with nasal congestion have a score 0.117 lower for "total hip replacement – smoke evacuator" ($p = 0.055$, marginally significant), 0.265 higher for "condyloma – inline filter ($p = 0.005$), and 0.178 lower for "colonoscopy – smoke evacuator" ($p = 0.009$).
- Individuals with nasal polyp have a score 0.959 lower for "condyloma – smoke evacuator" ($p < 0.001$).
- Individuals with bronchitis have a score 0.463 higher for "condyloma – inline filter" ($p = 0.006$) and 0.292 higher for "laparoscopic lysis – smoke evacuator" ($p = 0.055$, marginally significant).

- Individuals with other pulmonary symptoms have a score 0.507 lower for "laparoscopic lysis – inline filter" ($p = 0.037$) and 0.691 higher for "colonoscopy – suction only" ($p = 0.059$, marginally significant).
- The total symptom score is marginally significantly related to "tonsillectomy – smoke evacuator" ($p = 0.052$) with higher symptom scores indicating lower usage scores. The total symptom score is significantly related to "colonoscopy – smoke evacuator" ($p = 0.020$) with higher symptom scores indicating lower usage scores.

Although individual symptoms are related to various smoke evacuation practices, no relationships are consistent enough to be considered strong. It does appear there is some relationship between symptoms and the appropriate implementation of surgical smoke evacuation practices, although the relationship appears to be weak.

Perceptions of the Smoke Evacuation Recommendation Attributes

Each individual hypothesis is addressed in this section for the perceptions of the attributes of smoke evacuation recommendations.

H5. **When the perceptions of perioperative nurses are favorable regarding the attributes of relative advantage, compatibility, and observability of smoke evacuation recommendations, compliance with smoke evacuation recommendations increases.**

To test this hypothesis, regression analysis is used testing each of the variables (care efficiently, improve quality, ease of care, enhance effectiveness, control,

compatible, and fits practice) against each of the smoke evacuation practices. The significant findings are as follows:

- Being able to provide care more efficiently is significantly positively related to score on "total hip replacement – inline filter" ($p = 0.032$), marginally significantly positively related to score on "microlaryngoscopy – smoke evacuator" ($p = 0.051$) and significantly positively related to score on "colonoscopy – inline filter" ($p = 0.043$).
- Improving the quality of the work environment is significantly positively related to the score on "mastectomy – smoke evacuator" ($p = 0.039$) and significantly negatively related to the score on "total hip replacement – smoke evacuator" ($p = 0.045$).
- Making it easier to provide care is significantly positively related to the score on "mastectomy – smoke evacuator" ($p = 0.025$) and significantly positively related to the score on "total hip – inline filter" ($p = 0.035$).
- Enhancing effectiveness is significantly positively related to the score on "mastectomy – smoke evacuator" ($p = 0.015$), significantly positively related to the score on "laparoscopic lysis – inline filter" ($p = 0.016$), and significantly negatively related to the score on "laparoscopic lysis – suction only" ($p = 0.015$).
- Giving greater control is significantly positively related to the score on "mastectomy – smoke evacuator" ($p = 0.025$), significantly positively related to the score on "mastectomy – inline filter" ($p = 0.021$), significantly positively

related to the score on "total hip replacement– inline filter" (p = 0.021), significantly positively related to the score on "condyloma – inline filter" (p = 0.012), and significantly positively related to the score on "colonoscopy – inline filter" (p = 0.049).

- Being compatible with the role fulfilled by the nurse is significantly positively related to the score on "mastectomy – smoke evacuator" (p = 0.046), significantly positively related to the score on "mastectomy – inline filter" (p = 0.038), significantly positively related to the score on "condyloma – inline filter" (p = 0.017), significantly positively related to the score on "hemorroidectomy – inline filter" (p = 0.016), significantly positively related to the score on "laparoscopic lysis – inline filter" (p = 0.050), marginally significantly positively related to the score on "colonoscopy – inline filter" (p = 0.053)
- Fitting well with the way the nurse practices is significantly positively related to the score on "mastectomy – smoke evacuator" (p = 0.007).
- Fitting in with work style is significantly positively related to the score on "mastectomy – smoke evacuator" (p = 0.011), significantly positively related to the score on "mastectomy – inline filter" (p = 0.040), significantly positively related to the score on "condyloma – inline filter" (p = 0.048), significantly positively related to the score on "laparoscopic lysis – inline filter" (p = 0.034), significantly negatively related to the score on "laparoscopic lysis – suction only" (p = 0.035).

An overall summary of this data reflects that the attributes of giving greater control, being compatible with the role fulfilled by the nurse, and fitting in with work style are the most strongly related to implementation of appropriate surgical smoke evacuation recommendations. Figures 4, 5, and 6 illustrate the frequencies of these attributes, respectively, using the scale of 1 equals strongly disagree to 7 equals strongly agree.

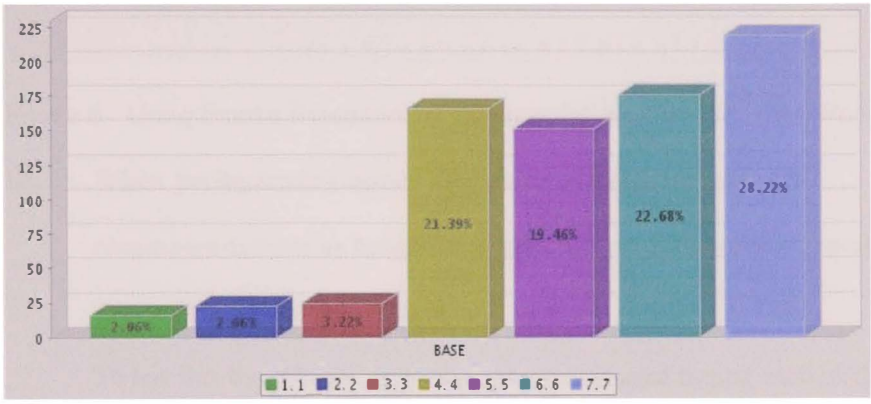

Figure 4. Complying with Smoke Evacuation Recommendations Gives Greater Control

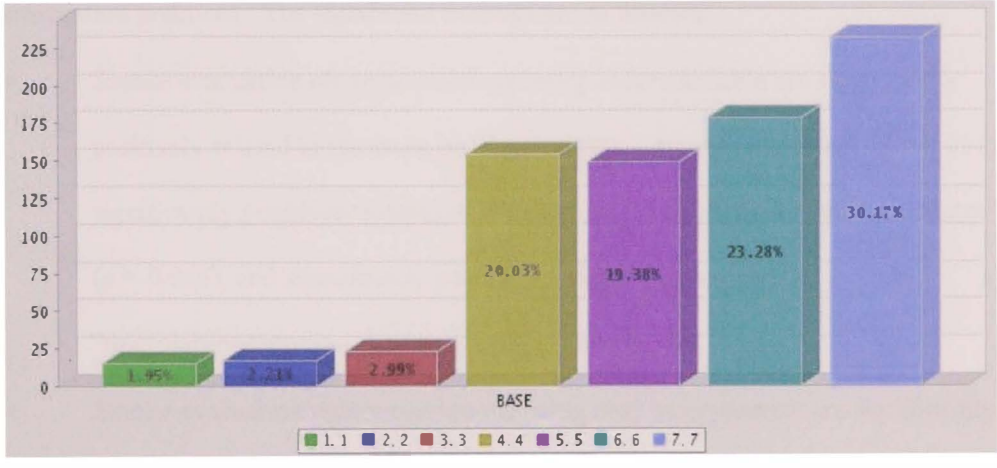

Figure 5. Using Smoke Evacuation Recommendations is Compatible with Role

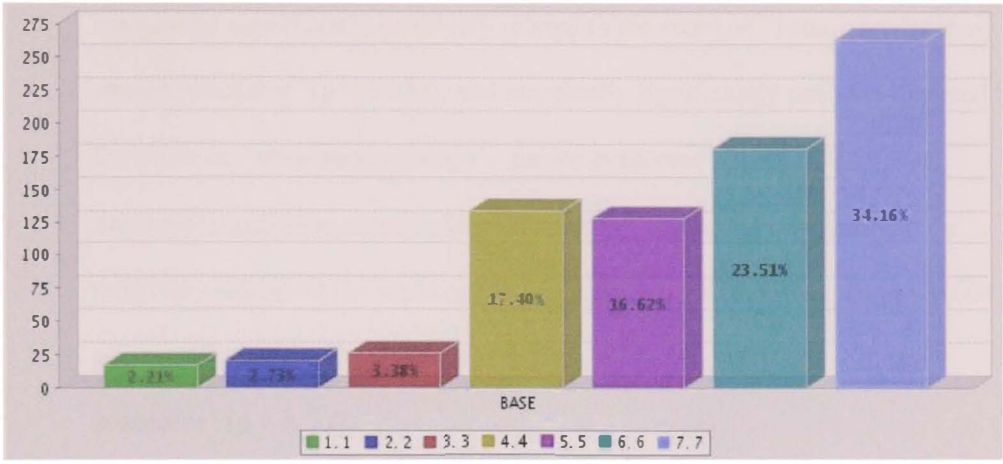

Figure 6. Using Smoke Evacuation Recommendations Fits Well into Work Style

H6. **When perioperative nurses perceive the smoke evacuation recommendations as being complex, then compliance with smoke evacuation recommendations will be low.**

To test this hypothesis, regression analysis is used testing each of the variables (understandable, implement easy, and easy to follow) against each of the smoke evacuation practices. The significant findings are as follows:

- Smoke evacuation recommendations being understandable are significantly positively related to the score on "mastectomy – smoke evacuator" ($p = 0.011$), significantly positively related to the score on "condyloma – smoke evacuator" ($p = 0.015$), and significantly positively related to the score on "microlaryngoscopy – smoke evacuator" ($p = 0.040$).
- Smoke evacuation recommendations being easy to implement are significantly positively related to the score on "mastectomy – smoke evacuator" ($p = 0.045$),

marginally significantly positively related to the score on "hemorrhoidectomy – smoke evacuator" ($p = 0.054$), and marginally significantly positively related to the score on "microlaryngoscopy – smoke evacuator" ($p = 0.049$).

- Smoke evacuation recommendations being easy to follow are significantly positively related to the score on "mastectomy – smoke evacuator" ($p = 0.004$), and significantly positively related to the score on "condyloma – smoke evacuator" ($p = 0.007$).

An overall summary for this section is that the perception of complexity appears to be strongly related to the use of a smoke evacuator but not as much with the inline filter or suction only use.

H7. **The higher the nurses rate specific barriers (as an obstacle to complying with smoke evacuation recommendations), the more likely the nurses are not going to comply with smoke evacuation recommendations.**

The barriers involved with this study are divided between the perception construct and the organizational innovativeness characteristics construct. When all of the responses are compared with the average rating (from 1 to 10, with 1 not being a barrier and 10 being a great barrier), the highest frequencies of the ratings for the barriers to the implementation of surgical smoke evacuation recommendations are physicians, equipment is not available, equipment is too noisy, and staff complacency, which are represented in H7 and H13. Figure 7 depicts this comparison in the frequencies of the average ratings for the barriers to the implementation of smoke evacuation recommendations.

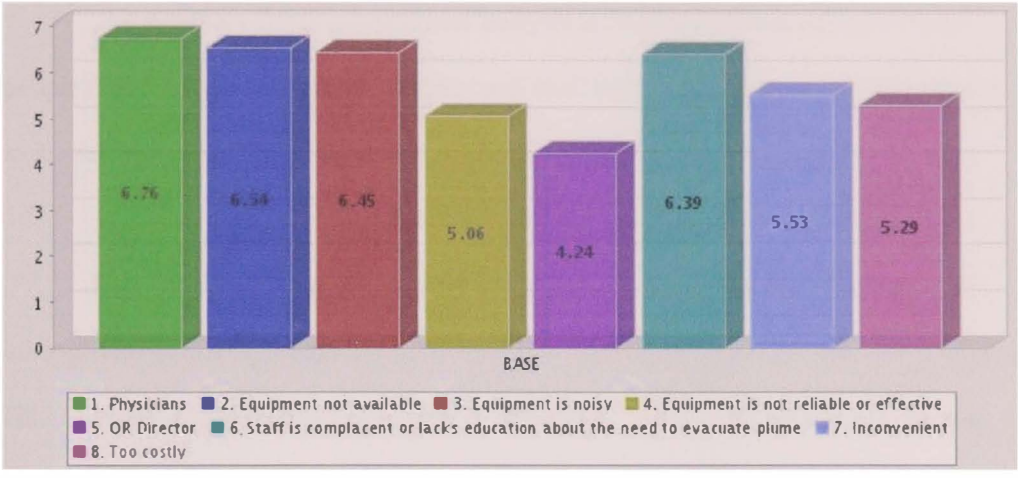

Figure 7. Barriers to Implementation of Smoke Evacuation Recommendations

To test H7, which that deals with the barriers of noise, reliability, inconvenience, and cost, regression analysis is used testing each of these variables against each of the procedures with different smoke evacuation options. The significant findings are as follows:

- Rating noise as a greater barrier is associated with a significantly lower score for "tonsillectomy – suction only" ($p = 0.033$) meaning nurses who rate noise as a barrier to compliance with smoke evacuation recommendations are more often using suction only during tonsillectomies.
- Rating equipment reliability as a greater barrier is associated with a significantly lower score for "condyloma – suction only" ($p = 0.012$).
- Rating cost as a greater barrier is associated with a significantly lower score for "condyloma – suction only" ($p = 0.021$).

The summary for this hypothesis analysis is that barriers not related to other people (noise, reliability, inconvenience, and cost) do not appear to be strongly related to implementation of surgical smoke evacuation recommendations.

Organizational Innovativeness Characteristics

Each individual hypothesis is addressed in this section for the organizational innovativeness characteristics.

H8. **When organizations are large in size, compliance with smoke evacuation recommendations increases.**

To test this hypothesis, t-tests and ANOVA models are used testing each of the variables against each of the smoke evacuation practices. The variables tested are Magnet status, locale (rural vs. urban), number of operating rooms (ORs), and number of cases. The first two were tested with t-tests, the latter two with ANOVAs. The significant findings are as follows:

- Magnet institutions score significantly higher (by 0.227) on "total hip replacement – smoke evacuator" ($p = 0.001$), significantly higher (by 0.014) on "total hip replacement – inline filter" ($p = 0.014$), significantly higher (by 0.231) on "condyloma – inline filter" ($p = 0.035$), significantly higher (by 0.209) on "laparoscopic lysis – inline filter" ($p = 0.035$), significantly higher (by 0.443) on "microlaryngoscopy – smoke evacuator" ($p < 0.001$), significantly higher (by 0.365) on "microlaryngoscopy – inline filter" ($p = 0.001$).
- Rural institutions score significantly lower (by 0.184) on "mastectomy – inline filter" ($p = 0.043$), significantly lower (by 0.187) on "tonsillectomy – inline

filter" ($p = 0.043$), significantly lower (by 0.251) on "condyloma – smoke evacuator" ($p = 0.023$), significantly lower (by 0.252) on "condyloma – inline filter" ($p = 0.020$), marginally significantly lower (by 0.172) on "hemorrhoidectomy – inline filter" ($p = 0.055$), significantly lower (by 0.148) on "colonoscopy – smoke evacuator" ($p = 0.034$).

- Number of ORs is significantly related to the score on "tonsillectomy – smoke evacuator" ($p = 0.013$), "condyloma – inline filter" ($p = 0.017$), "microlaryngoscopy – smoke evacuator" ($p = 0.003$), and "microlaryngoscopy – inline filter" ($p = 0.007$), and "colonoscopy – smoke evacuator" ($p = 0.023$). Post-hoc Tukey tests find that for "condyloma – inline filter," institutions with fewer than five ORs score significantly lower than institutions with more than 10, for both "microlaryngoscopy" procedures institutions with fewer than 11 ORs score significantly lower than institutions with more than 20, and for "colonoscopy – smoke evacuator" institutions with fewer than 20 ORs score significantly lower than institutions with more than 20.
- Number of cases is significantly related to score on "tonsillectomy – smoke evacuator" ($p = 0.031$), "microlaryngoscopy – smoke evacuator" ($p = 0.013$), and "microlaryngoscopy – inline filter" ($p = 0.012$), and "colonoscopy – suction only" ($p = 0.029$). Post-hoc Tukey tests find that for "colonoscopy – suction only" institutions with 26 – 50 cases score significantly lower than institutions with 201 – 250.

The responses between the division between rural and urban hospitals is quite evident with the larger percentage of nurses working in urban facilities. Figure 8 illustrates the frequency of response difference between rural and urban facilities.

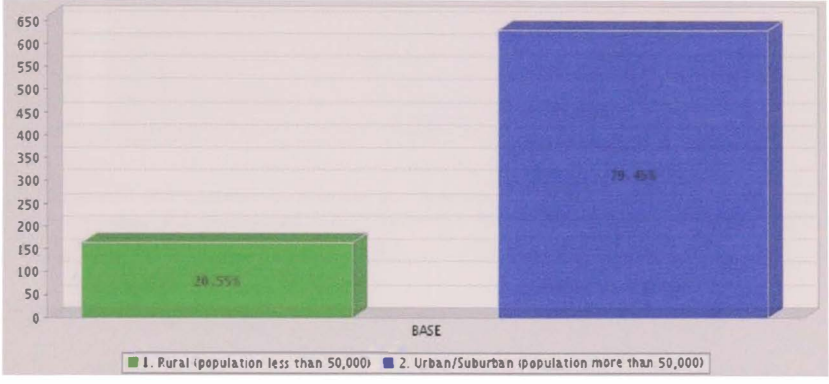

Figure 8. Responses from Rural Facilities and Urban Facilities

In summary, there appears to be a trend that larger institutions implement smoke evacuation recommendations more fully. The strongest evidence, however, is in the split between rural and urban, where healthcare facilities in rural settings implement several of the recommended procedures at a lower level than urban hospitals. Therefore, healthcare facilities in urban or suburban areas (population more than 50,000) tend to implement smoke evacuation recommendations more frequently.

H9. **When organizations exhibit greater complexity, compliance with smoke evacuation recommendations increases.**

Regression analysis is used to assess the relationship between the number of different types of specialties offered in the institution and the adherence to smoke evacuation. Figure 9 portrays the frequencies of the different types of specialties provided at the participant's facility.

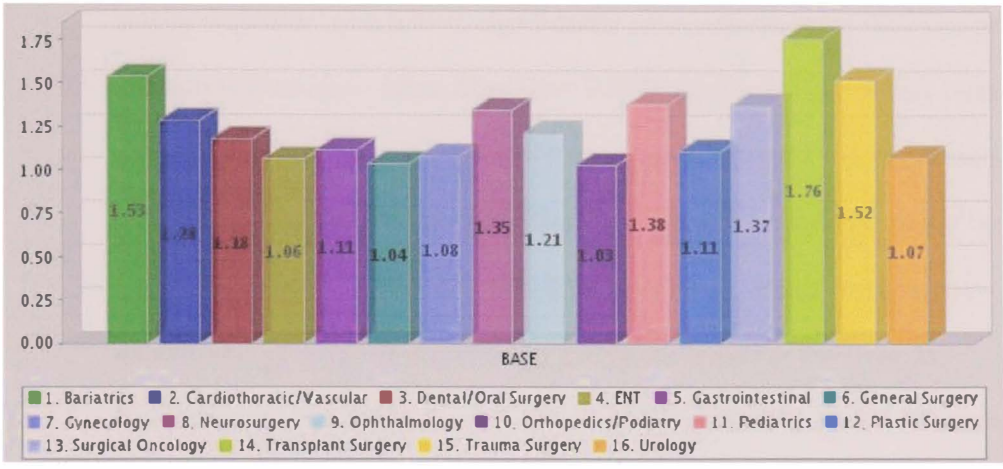

Figure 9. Surgical Service Specialties

The survey responses indicate whether a particular specialty is offered with 1 being "yes" and 2 being "no." Therefore, the lower the number, the more positive the responses are. For example, in this study the five most common specialties identified by the nurses are orthopedics/podiatry, general surgery, ENT, urology, and gynecology. The specialty services least common are transplant surgery, bariatrics, and trauma surgery. The significant findings are as follows:

- An increasing number of different specialty procedures performed in the institution is significantly positively related to the score on "total hip replacement – smoke evacuator" ($p = 0.002$), significantly positively related to the score on "tonsillectomy – smoke evacuator" ($p = 0.050$), significantly positively related to the score on "tonsillectomy – inline filter" ($p = 0.049$), significantly positively related to the score on "condyloma – suction only" ($p = 0.025$), significantly positively related to the score on "hemorrhoidectomy –

smoke evacuator" ($p = 0.010$), significantly positively related to the score on "hemorrhoidectomy – inline filter" ($p = 0.037$), significantly positively related to the score on "laparoscopic lysis – smoke evacuator" ($p = 0.045$), significantly positively related to the score on "microlaryngoscopy – smoke evacuator" ($p = 0.010$), significantly positively related to the score on "microlaryngoscopy – inline filter" ($p = 0.010$), significantly positively related to the score on "colonoscopy – smoke evacuator" ($p = 0.006$), significantly positively related to the score on "colonoscopy – inline filter" ($p = 0.022$).

In summary, this study demonstrates that locations that offer a great number of specialties have better compliance with smoke evacuation recommendations. This finding is consistent with the finding for H8 that states compliance increases in larger facilities.

H10. **When organizations exhibit greater interconnectedness, compliance with smoke evacuation recommendations increases.**

Separate regression models are fit for each combination of connectedness variables (open communication, decision making, cooperation, nursing and medical concerns, coordination, collaboration, and satisfaction) and smoke evacuation recommendations. The significant findings are as follows:

- Higher levels of open communication are significantly positively related to the score on "mastectomy – smoke evacuator" ($p = 0.034$), significantly positively related to the score on "total hip replacement – smoke evacuator" ($p = 0.042$), marginally significantly positively related to the score on "total hip replacement

"hemorrhoidectomy – suction only" ($p = 0.052$), and significantly positively related to the score on "laparoscopic lysis – inline filter" ($p = 0.013$).

- Higher levels of coordination between physicians and nurses are significantly positively related to the score on "mastectomy – smoke evacuator" ($p = 0.004$), significantly positively related to the score on "total hip replacement – smoke evacuator" ($p = 0.044$), significantly positively related to the score on "total hip replacement – inline filter" ($p = 0.045$), significantly positively related to the score on "tonsillectomy – smoke evacuator" ($p = 0.035$), significantly positively related to the score on "condyloma – smoke evacuator" ($p = 0.003$), significantly positively related to the score on "hemorrhoidectomy – smoke evacuator" ($p = 0.044$), significantly positively related to the score on "laparoscopic lysis – smoke evacuator" ($p = 0.009$), significantly positively related to the score on "laparoscopic lysis – suction only" ($p = 0.036$), and significantly positively related to the score on "colonoscopy – smoke evacuator" ($p = 0.030$).
- Higher levels of collaboration between physicians and nurses are significantly positively related to the score on "mastectomy – smoke evacuator" ($p = 0.002$), significantly positively related to the score on "total hip replacement – smoke evacuator" ($p = 0.038$), significantly positively related to the score on "tonsillectomy – smoke evacuator" ($p = 0.024$), significantly positively related to the score on "condyloma – smoke evacuator" ($p = 0.004$), significantly positively related to the score on "hemorrhoidectomy – smoke evacuator" ($p =$

0.047), and significantly positively related to the score on "laparoscopic lysis – smoke evacuator" (p = 0.006).

- Higher levels of satisfaction with the way decisions are made are significantly positively related to the score on "mastectomy – smoke evacuator" (p = 0.003), significantly positively related to the score on "total hip replacement – smoke evacuator" (p = 0.048), significantly positively related to the score on "total hip replacement – inline filter" (p = 0.022), significantly **negatively** related to the score on "total hip replacement – suction only" (p = 0.034), significantly positively related to the score on "tonsillectomy – smoke evacuator" (p = 0.006), significantly positively related to the score on "condyloma – smoke evacuator" (p = 0.003), significantly positively related to the score on "hemorrhoidectomy – smoke evacuator" (p = 0.010), significantly **negatively** related to the score on "hemorrhoidectomy – suction only" (p = 0.035), significantly positively related to the score on "laparoscopic lysis – smoke evacuator" (p = 0.030), significantly **negatively** related to the score on "laparoscopic lysis – suction only" (p = 0.031), significantly positively related to the score on "colonoscopy – smoke evacuator" (p = 0.027), and significantly **negatively** related to the score on "colonoscopy – suction only" (p = 0.031).

In summary, greater interconnectedness does appear to be associated with greater implementation of smoke evacuation recommendations. However, there are some odd findings here. Specifically, higher levels of satisfaction were associated with

greater use of "suction only" for many procedures as well as being associated with higher levels of the use of other smoke evacuation methods.

H11. **When organizations show leadership support, compliance with smoke evacuation recommendations increases.**

For this hypothesis, ANOVA is used to assess relationships using the four support variables as the independent factors. These variables include support from the OR Director when implementing AORN research-based recommended practices, support from the OR Director when implementing AORN recommended practices on smoke evacuation, support from the OR Director when implementing the healthcare facility's policies and procedures regarding smoke evacuation, and support from the physician when implementing smoke evacuation practices.

- Support from the OR Director when implementing AORN research-based recommended practices (in general) is significantly related to the score on "mastectomy – smoke evacuator" ($p = 0.012$), "total hip replacement – suction only" ($p = 0.005$), "tonsillectomy – suction only" ($p = 0.001$), "condyloma – smoke evacuator" ($p = 0.005$), "hemorrhoidectomy – smoke evacuator" ($p = 0.002$), "hemorrhoidectomy – suction only" ($p = 0.011$), "laparoscopic lysis – inline filter" ($p = 0.006$), "microlaryngoscopy – inline filter" ($p = 0.047$), and "colonoscopy – suction only" ($p = 0.002$). Post-hoc Tukey tests find that for "total hip replacement – suction only" individuals answering "Never" score higher than others, for "tonsillectomy – suction only" individuals answering "Never" score higher than individuals answering "Always," for "laparoscopic

lysis – inline filter" individuals answering "Always" score higher than individuals answering "Never," for "microlaryngoscopy lysis – inline filter" individuals answering "Always" score higher than individuals answering "Never," and for "colonoscopy – suction only" individuals answering "Never" score higher than others.

- Support from the OR Director when implementing AORN recommended practices on surgical smoke evacuation is significantly related to score on "mastectomy – smoke evacuator" ($p < 0.001$), "mastectomy – inline filter" ($p = 0.004$), "total hip replacement – smoke evacuator" ($p = 0.001$), "total hip replacement – inline filter" ($p = 0.001$), "tonsillectomy – smoke evacuator" ($p < 0.001$), "tonsillectomy – inline filter" ($p = 0.002$), "tonsillectomy – suction only" ($p = 0.039$), "condyloma – smoke evacuator" ($p < 0.001$), "condyloma – inline filter" ($p = 0.009$), "hemorrhoidectomy – smoke evacuator" ($p < 0.001$), "hemorrhoidectomy – inline filter" ($p = 0.004$), "laparoscopic lysis – smoke evacuator" ($p = 0.002$), "laparoscopic lysis – inline filter" ($p < 0.001$), "microlaryngoscopy – smoke evacuator" ($p = 0.011$), "microlaryngoscopy – inline filter" ($p < 0.001$), "colonoscopy – smoke evacuator" ($p = 0.008$), "colonoscopy – inline filter" ($p < 0.001$), and "colonoscopy – suction only" ($p = 0.005$). Post-hoc Tukey tests find that for "mastectomy – smoke evacuator" individuals answering "Never" score lower than others, for "mastectomy – inline filter" individuals answering "Never" score lower than individuals answering "Always", for "total hip replacement – smoke evacuator" individuals

answering "Never" score lower than others, for "total hip replacement – inline filter" individuals answering "Never" score lower than others, for "tonsillectomy – smoke evacuator" individuals answering "Always" score higher than others, for "tonsillectomy – inline filter" individuals answering "Never" score lower than others, for "tonsillectomy – suction only" individuals answering "Never" score higher than individuals answering "Always", for "condyloma – smoke evacuator" individuals answering "Never" score lower than others, for "condyloma – inline filter" individuals answering "Never" score lower than others, for "hemorrhoidectomy – smoke evacuator" individuals answering "Always" score higher than others, for "hemorrhoidectomy – inline filter" individuals answering "Never" score lower than others, for "laparoscopic lysis – smoke evacuator" individuals answering "Never" score lower than individuals answering "Always," for "mastectomy laparoscopic lysis – inline filter" individuals answering "Never" score lower than others and individuals answering "Sometimes" score lower than individuals answering "Always," for "microlaryngoscopy – smoke evacuator" individuals answering "Never" score lower than others, for "microlaryngoscopy – inline filter" individuals answering "Never" score lower than others, for "colonoscopy – smoke evacuator" individuals answering "Never" score lower than individuals answering "Always," for "colonoscopy – inline filter" individuals answering "Never" score lower than others, for "colonoscopy – suction only" individuals answering "Never" score higher than others.

- Support from the OR Director when implementing OR policies related to smoke evacuation is significantly related to score on "mastectomy – smoke evacuator" ($p < 0.001$), "mastectomy – inline filter" ($p = 0.008$), "total hip replacement – smoke evacuator" ($p = 0.005$), "total hip replacement – inline filter" ($p = 0.027$), "tonsillectomy – smoke evacuator" ($p < 0.001$), "tonsillectomy – inline filter" ($p = 0.028$), "tonsillectomy – suction only" ($p = 0.012$), "condyloma – smoke evacuator" ($p < 0.001$), "condyloma – inline filter" ($p = 0.009$), "hemorrhoidectomy – smoke evacuator" ($p < 0.001$), "hemorrhoidectomy – inline filter" ($p = 0.011$), "hemorrhoidectomy – suction only" ($p = 0.029$), "laparoscopic lysis – smoke evacuator" ($p = 0.003$), "laparoscopic lysis – inline filter" ($p < 0.001$), "microlaryngoscopy – smoke evacuator" ($p = 0.016$), "microlaryngoscopy – inline filter" ($p = 0.001$), "microlaryngoscopy – suction only" ($p = 0.015$), "colonoscopy – smoke evacuator" ($p = 0.041$), "colonoscopy – inline filter" ($p < 0.001$), and "colonoscopy – suction only" ($p < 0.001$). Post-hoc Tukey tests find that for "mastectomy – smoke evacuator" individuals answering "Always" score higher than others, for "mastectomy – inline filter" individuals answering "Never" score lower than individuals answering "Always", for "total hip replacement – smoke evacuator" individuals answering "Never" score lower than individuals answering "Always," for "total hip replacement – inline filter" individuals answering "Never" score lower than individuals answering "Always," for "tonsillectomy – smoke evacuator" individuals answering "Always" score higher than others, for "tonsillectomy –

inline filter" individuals answering "Never" score lower than others, for "tonsillectomy – suction only" individuals answering "Never" score lower than others, for "condyloma – smoke evacuator" individuals answering "Never" score lower than others, for "hemorrhoidectomy – smoke evacuator" individuals answering "Always" score higher than individuals answering "Never," for "hemorrhoidectomy – inline filter" individuals answering "Never" score lower than others, for "laparoscopic lysis – smoke evacuator" individuals answering "Never" score lower than individuals answering "Always," for "laparoscopic lysis – inline filter" individuals answering "Never" score lower than others, for "microlaryngoscopy – smoke evacuator" individuals answering "Never" score lower than others, for "microlaryngoscopy – inline filter" individuals answering "Never" score lower than others, for "colonoscopy – smoke evacuator" individuals answering "Never" score lower than individuals answering "Always," for "colonoscopy – inline filter" individuals answering "Never" score lower than others, for "colonoscopy – suction only" individuals answering "Never" score higher than others.

- Support from physicians when implementing smoke evacuation practices is significantly related to score on "mastectomy – smoke evacuator" ($p < 0.001$), "mastectomy – suction only" ($p = 0.030$), "total hip replacement – smoke evacuator" ($p = 0.012$), "tonsillectomy – smoke evacuator" ($p < 0.001$), "condyloma – smoke evacuator" ($p = 0.007$), "hemorrhoidectomy – smoke evacuator" ($p = 0.002$), "laparoscopic lysis – smoke evacuator" ($p = 0.001$),

"laparoscopic lysis – inline filter" ($p = 0.056$, marginally significant), "laparoscopic lysis – suction only" ($p = 0.017$), "colonoscopy – smoke evacuator" ($p = 0.007$), and "colonoscopy – suction only" ($p = 0.018$). Post-hoc Tukey tests find that for "mastectomy – suction only" individuals answering "Never" score lower than others, for "total hip replacement – smoke evacuator" individuals answering "Never" score lower than individuals answering "Always," for "tonsillectomy – smoke evacuator" individuals answering "Always" score higher than others, "condyloma – smoke evacuator" individuals answering "Never" score lower than individuals answering "Always," for "hemorrhoidectomy – smoke evacuator" individuals answering "Always" score higher than individuals answering "Never," for "laparoscopic lysis – smoke evacuator" individuals answering "Never" score lower than individuals answering "Always," for "laparoscopic lysis – inline filter" individuals answering "Never" score lower than others, for "laparoscopic lysis – suction only" individuals answering "Never" score lower than individuals answering "Always," for "colonoscopy – smoke evacuator" individuals answering "Never" score lower than individuals answering "Always," for "colonoscopy – suction only" individuals answering "Never" score higher than others.

Although there are some findings that seem to be in the wrong order (for example, in the section on support for implementing general AORN research-based practices, there are several cases where individuals who report never getting support scoring higher on average than individuals who reported always getting support), the

overall pattern suggests that leadership support is strongly associated with greater compliance with smoke evacuation recommendations.

Of interest is the frequency of the direct responses from nurses stating that they get support from the operating room director when smoke evacuation practices are implemented as compared to physician support. This is illustrated in Figures 10 and 11, respectively.

Figure 10. Support from the OR Director when Implementing Smoke Evacuation Recommendations

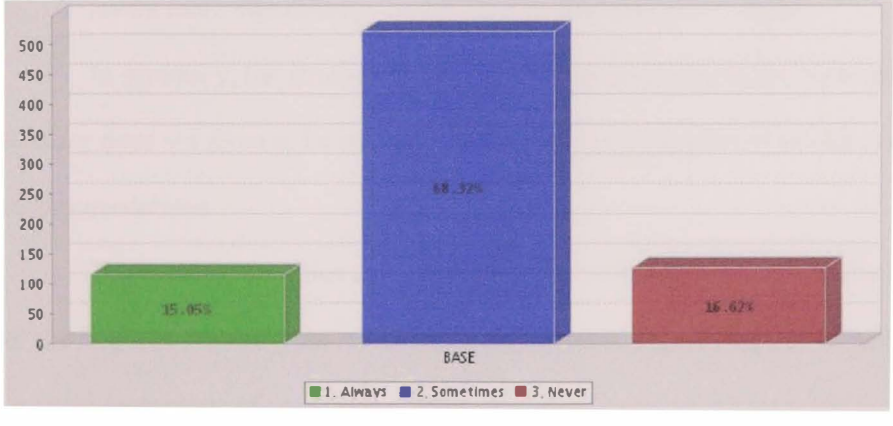

Figure 11. Support from Physicians when Implementing Smoke Evacuation Recommendations

H12. **When organizations have a high level of formalization, then compliance with smoke evacuation recommendations will be low.**

For this test, ANOVA is used to compare adherence to smoke evacuation recommendations by the number of levels of management above the staff and the number of levels of management above the director. Greater numbers of levels of management can indicate a higher level of formalization and bureaucracy because more people exist in the chain of command. The significant findings are as follows:

- Number of levels of management above the staff is significantly related to the score on "condyloma – smoke evacuator" ($p = 0.025$), "condyloma – suction only" ($p = 0.013$), and "colonoscopy – suction only" ($p = 0.049$). Post-hoc Tukey tests find that for "condyloma – smoke evacuator" institutions with 4 levels score significantly higher than institutions with 1 level, for "condyloma – suction only" institutions with two or four levels score significantly higher than institutions with 1 level, for "colonoscopy – suction only" institutions with four levels score significantly higher than institutions with 1 level.

In summary, the number of levels of management above the nurse and above the director does not seem to be strongly related to implementation of smoke evacuation recommendations.

The types of facilities are also considered with this hypothesis. The frequencies of the responses to the types of facilities are shown in Figures 12 and 13 with the greatest percentage of responses coming from perioperative nurses working in non-

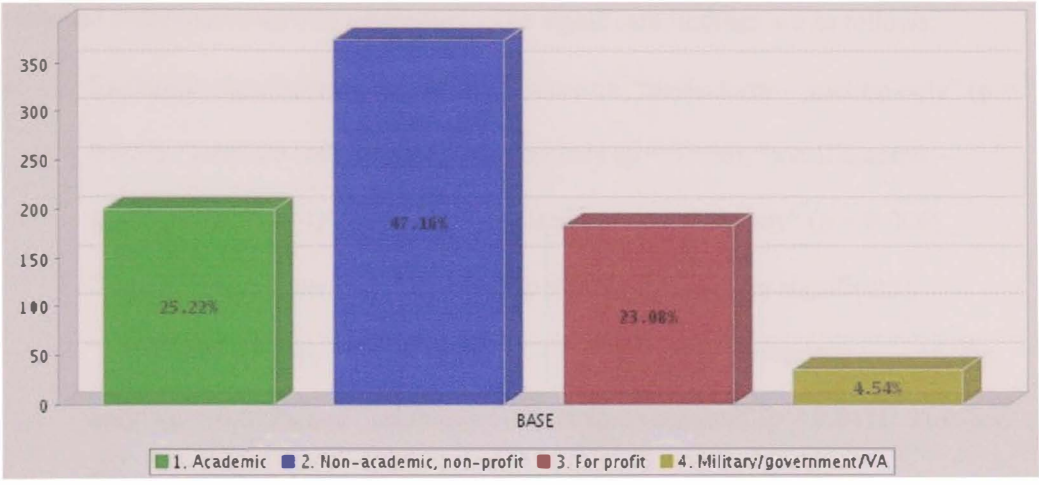

Figure 12. Type of Healthcare Facility

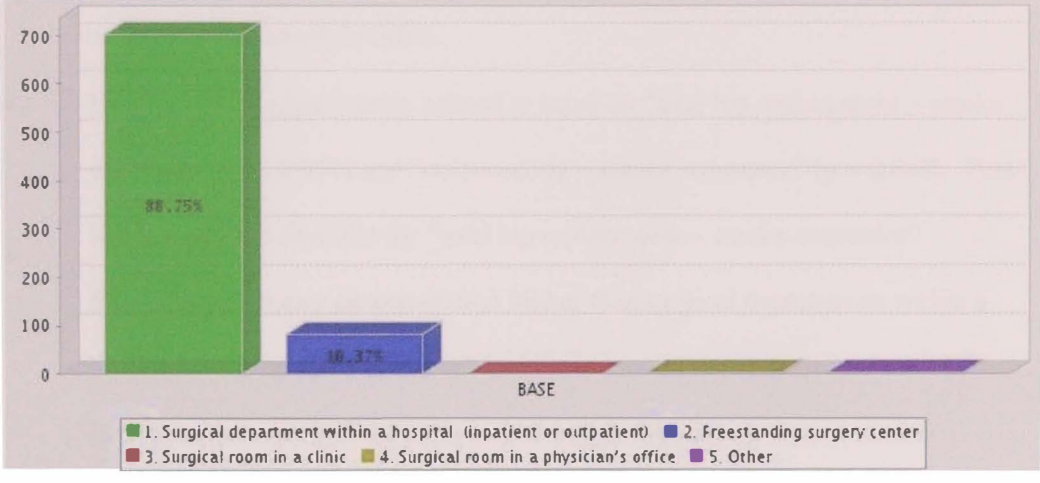

Figure 13. Surgical Facility Type

academic, non-profit facilities with the surgical department being within the hospital setting.

For hypothesis testing, ANOVAs are used with "facility" and "facility" type as the independent variables. For "facility," one entry of "10" was found in the data and

removed before analysis was performed. The significant findings are as follows:

- Facility is significantly related to the score on "mastectomy – suction only" ($p = 0.027$), "total hip replacement – suction only ($p = 0.006$), "tonsillectomy – smoke evacuator" ($p = 0.015$), "tonsillectomy – suction only" ($p = 0.006$), "hemorrhoidectomy – suction only" ($p = 0.053$, marginally significant), "microlaryngoscopy – inline filter" ($p = 0.010$), "microlaryngoscopy – suction only" ($p = 0.018$), and "colonoscopy – smoke evacuator" ($p = 0.041$). Post-hoc Tukey tests find that for "microlaryngoscopy – inline filter" and "microlaryngoscopy – suction only" academic facilities scored higher than military/government facilities.
- Facility type is significantly related to score on "total hip replacement – smoke evacuator" ($p < 0.001$) and "colonoscopy – smoke evacuator" ($p = 0.049$). Post-hoc Tukey tests find that for "total hip replacement – smoke evacuator" freestanding surgery centers scored higher than surgical departments within a hospital and others.

In summary, academic facilities scored higher than military/government facilities with the proper evacuation of surgical smoke. Freestanding surgery centers scored higher than surgical departments within hospitals for the implementation of smoke evacuation practices.

H13. **The higher the nurses rate specific organizational barriers (as an obstacle to complying with smoke evacuation recommendations), the more likely the nurses are not going to comply with smoke evacuation recommendations.**

To test this hypothesis, regression analysis is used testing each of the variables (complacency, physicians, equipment availability, and OR director) against each of the smoke evacuation practices. See hypothesis 7 for more information that is displayed in Figure 7. The significant findings for this hypothesis are as follows:

- Rating noise as a greater barrier is associated with a significantly lower score for "hemorrhoidectomy – smoke evacuator" ($p = 0.057$), a significantly lower score for "microlaryngoscopy – smoke evacuator" ($p = 0.005$).
- Rating the OR director as a greater barrier is associated with a significantly lower score for "condyloma – smoke evacuator" ($p = 0.024$).

In summary, organizational barriers do not appear to be significantly related to the implementation of smoke evacuation recommendations. However, when the response frequencies are plotted for each perceived barrier, the greatest barriers perceived are equipment availability, physicians, noise, and staff complacency. These barriers are all illustrated in Figures 14 15, 16, and 17. The following scale is used for these graphs: 1 = not a perceived barrier to 10 = perceived as the greatest barrier. Approximately 28 percent of the participants rate equipment availability as the greatest barrier, 22 percent rate physicians as the greatest barrier, 19 percent rate noise of the equipment is the greatest barrier, and 19 percent rate staff complacency as the greatest barrier. In comparison, when the OR Director is graphed as a perceived barrier, the results note that most of the responses (over 30 percent score 1 on the survey) did not perceive the OR Director as a barrier to implementing smoke evacuation recommendations as shown in Figure 18.

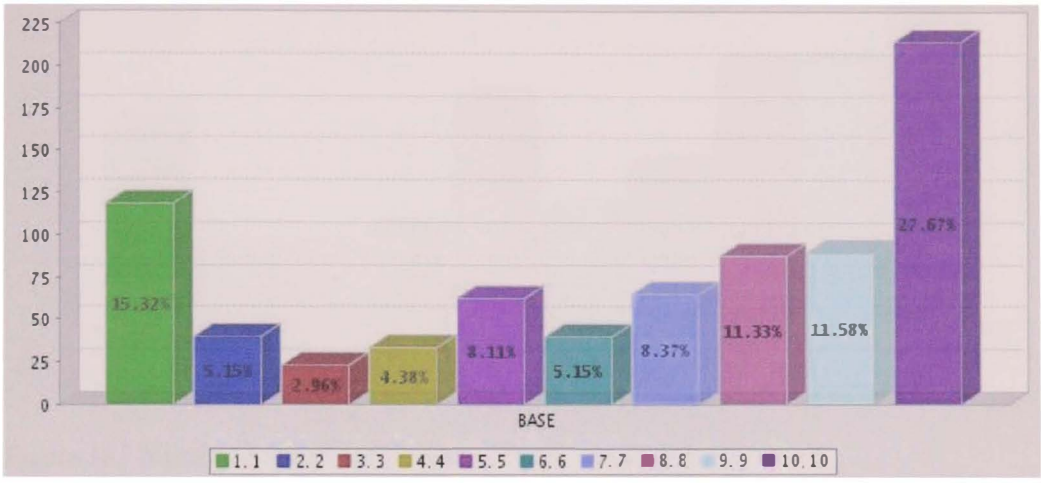

Figure 14. Equipment Availability as a Perceived Barrier

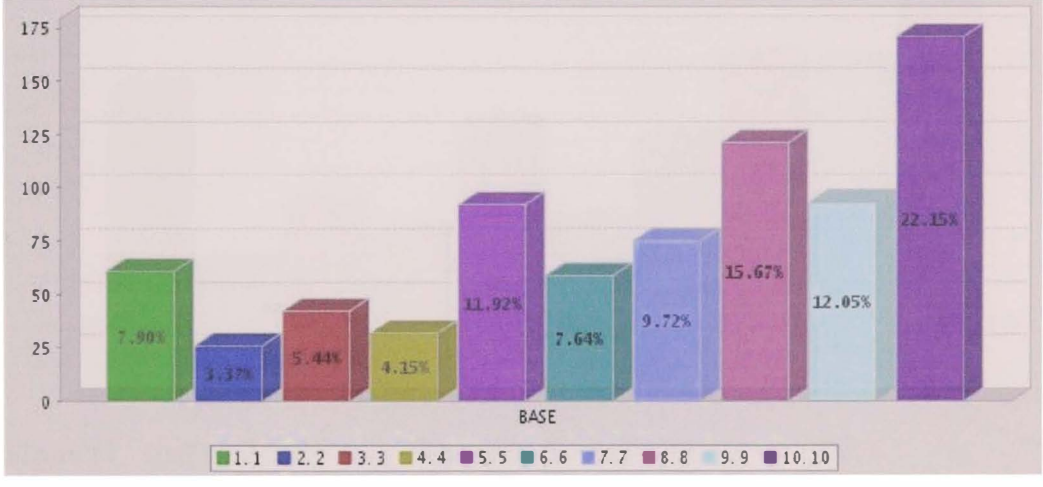

Figure 15: Physician as a Perceived Barrier

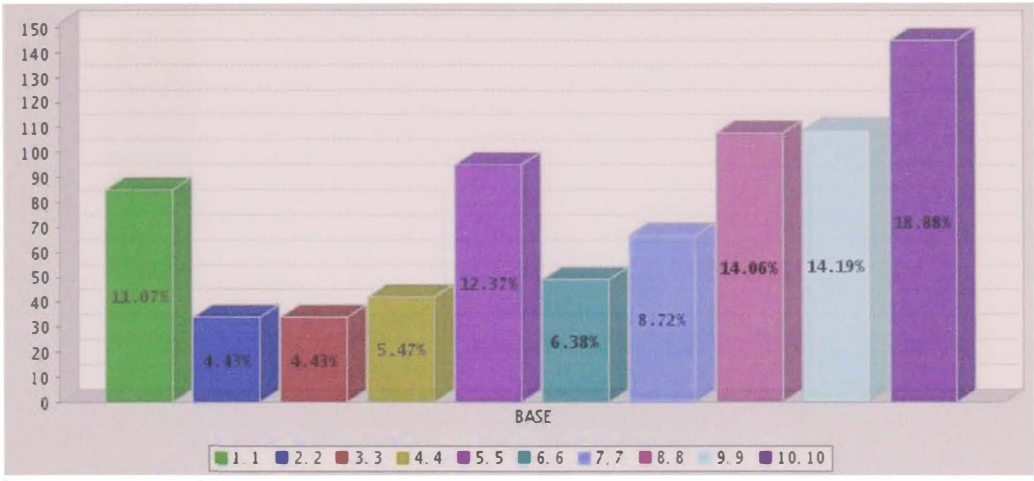

Figure 16. Noise as a Perceived Barrier

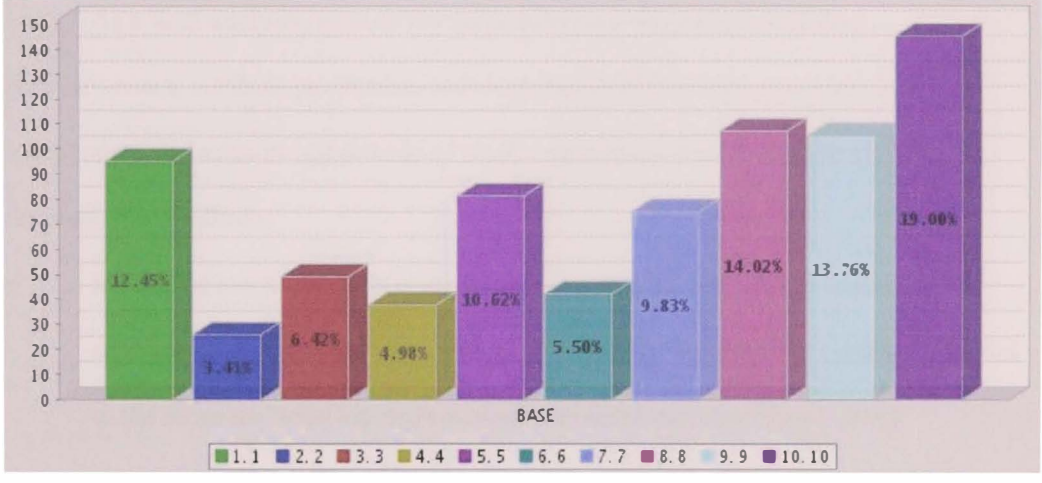

Figure 17. Staff Complacency as a Perceived Barrier

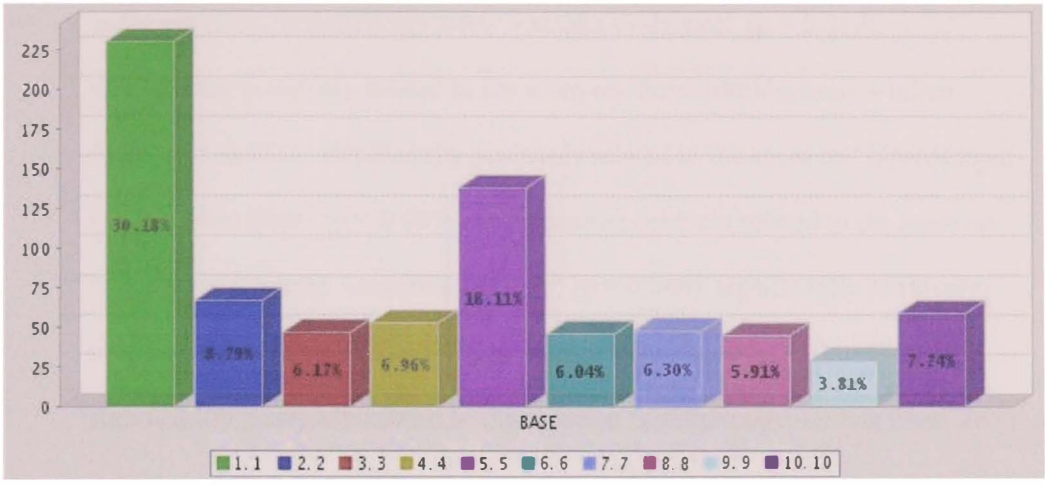

Figure 18: OR Director as a Perceived Barrier

Additional Analyses

As a final analysis, each of the three summary scores for individual innovativeness, attribute perception, and organizational innovativeness are used as independent variables in regressions of smoke evacuation practices. The significant findings are as follows:

- Individual innovativeness is marginally significantly positively related to the score on "mastectomy – inline filter" ($p = 0.008$), significantly positively related to the score on "total hip replacement – smoke evacuator" ($p = 0.044$), significantly positively related to the score on "total hip replacement – inline filter" ($p = 0.004$), significantly positively related to the score on "tonsillectomy – smoke evacuator" ($p = 0.024$), significantly positively related to the score on "tonsillectomy – inline filter" ($p = 0.020$), marginally positively related to the score on "condyloma – inline filter" ($p = 0.057$), significantly positively related

to the score on "hemorrhoidectomy – smoke evacuator" ($p = 0.019$), significantly positively related to the score on "hemorrhoidectomy – inline filter" ($p = 0.033$), significantly positively related to the score on "laparoscopic lysis – inline filter" ($p = 0.001$), significantly positively related to the score on "microlaryngoscopy – smoke evacuator" ($p = 0.048$), significantly positively related to the score on "colonoscopy – smoke evacuator" ($p = 0.019$), and significantly positively related to the score on "colonoscopy – inline filter" ($p = 0.011$).

- Perception is significantly positively related to the score on "mastectomy – smoke evacuator" ($p = 0.007$), and marginally significantly positively related to the score on "condyloma – smoke evacuator" ($p = 0.053$).
- Organizational innovativeness is significantly positively related to "mastectomy – smoke evacuator" ($p = 0.015$).

In summary, individual innovativeness seems strongly related to the use of smoke evacuator and inline filter, but perception and organizational innovativeness do not seem to be as strongly related to compliance with smoke evacuation recommendations.

Summary

The data presented has revealed some interesting and logical information but also has provided some surprising results. Outcomes note the significance of increased education and training along with positive perceptions of the attributes of smoke evacuation recommendations (relative advantage, compatibility, complexity, and

observability), larger healthcare organizations, and strong leadership support all positively influence compliance with smoke evacuation recommendations. Chapter V will discuss these findings in more detail and their impact on designing educational offerings that target those who do not comply with smoke evacuation recommendations as fully as they should.

CHAPTER V: INTERPRETATION

This chapter provides an overview of the problem and a brief summary of the study. Significant findings are discussed and compared with previous research. Unanticipated outcomes are revealed that present surprising results. Conclusions based on the data in Chapter IV are offered with limitations and implications for action being proposed. Recommendations for further research are highlighted and concluding remarks about the study are provided.

Overview of the Problem and Summary of the Study

Even though air pollution concerns have grown during the past decade, not a lot of emphasis has been placed on the inhalation of surgical smoke in operating room environments. Surgical smoke has been shown to contain toxic gases and small particulate that are hazardous when inhaled. Also the high potential for the transmission of viable organisms within the plume has been revealed. Professional organizations and agencies have supported the classification of surgical smoke as an inhalation hazard and have published recommendations for smoke evacuation that foster a clean air environment in the operating room. In 2009, research is lacking that explores indicators that have a significant influence on smoke evacuation practices. Therefore, the purpose of this study is to determine key indicators that are associated

with different levels of compliance with smoke evacuation recommendations by perioperative nurses.

The research questions that are addressed in this study are:

1. What innovativeness characteristics of perioperative nurses influence the level of compliance with smoke evacuation recommendations? (The independent variables associated with this research question include age, education, experience, knowledge, training, and incidence of respiratory problems by perioperative nurses.)
2. What perceptions by perioperative nurses of the attributes of smoke evacuation recommendations influence the level of compliance with smoke evacuation recommendations? (The independent variables associated with this research question include perceptions of the attributes of relative advantage, compatibility, observability, complexity, and barriers to the implementation of smoke evacuation recommendations.)
3. What organizational innovativeness characteristics influence the level of compliance with smoke evacuation recommendations? (The independent variables associated with this research question include organization size, complexity, interconnectedness, leadership support, formalization, and organizational barriers to the implementation of smoke evacuation recommendations.)

Determining why smoke evacuation recommendations are not consistently being followed provides valuable information to perioperative professionals so that powerful

educational programs can be created and other campaigns and activities can be provided to encourage smoke evacuation practices during all surgical procedures that create plume.

This descriptive explanatory and exploratory study employs an online survey that was offered to a random sampling of 4000 perioperative staff nurses who are members of AORN. The survey tool was created with advice from experts on surgical smoke and then finalized after two pilot offerings. Question Pro was the vehicle used for the survey tool. The survey was available from December 8, 2008 until January 30, 2009, with 777 participants completing the questionnaire. Results were automatically gathered in an Excel spreadsheet and transferred into SPSS for statistical analyses.

Statistical analyses of the data involve two stages. During the first stage, descriptive statistical measures are analyzed to note variations in the independent variables and the dependent variable. The second stage involves hypotheses testing using different bivariate techniques (two-sample t-tests, regressions, and one-way analyses of variance) for the analyses.

The major findings of this study note that increased education and training along with positive perceptions of the attributes of smoke evacuation recommendations, as being less complex and easier to follow, increase compliance with surgical smoke evacuation recommendations. Larger healthcare organizations with a variety of specialties, increased interconnectedness, and strong leadership support also positively influence compliance with smoke evacuation recommendations. These findings are described in more detail in the following sections.

Major Findings as Related to the Literature

Since the reliability scores were high for all three areas of individual innovativeness characteristics, perception of the smoke evacuation recommendation attributes, and organizational innovativeness characteristics in the study survey, this instrument demonstrates internal consistently with the indicators that influence compliance with smoke evacuation recommendations. Because the Cronbach's alpha for each of the areas is over 0.7, reliability has been shown so one can depend on the survey to produce viable information.

The AORN demographics are very similar to the study demographics involving average age, education, and states of employment as shown in Table 5. The average age of AORN members is 47 years while the average age of the participants in the study is 51 years. This is very comparable as the ages are only 4 years apart. But since the survey participants' average age is older, these nurses may have had more time to complete the survey due to less family commitments. Since the survey results indicate that age is not a factor in smoke evacuation compliance, one cannot suggest that older nurses may be more passionate about this topic. The educational levels achieved by the participants are every similar to the AORN membership universe, especially for the Associate Degree and Diploma prepared nurses. All states are represented in the study. Ohio, Georgia, and Massachusetts are used as representative states to see if they were comparable with the AORN membership. For example, approximately 2.43 percent of AORN membership is from Georgia. Approximately 2.90 percent of the survey participants reported working in Georgia, which is very comparable. Even though these

comparisons are subjective, they demonstrate that the survey participants are representative of the AORN active member universe; therefore, the results can be generalized to the AORN membership population quite confidently.

Smoking is not handled as a co-variant because there are no significant differences between the groups when smoking is included as a co-variant. Even though 94.31 percent of the participants are nonsmokers, approximately 33.69 percent of those nonsmokers reported that they had smoked in the past. With over one-third of the nonsmokers quitting the smoking habit, one would logically assume that they must realize the health concerns with inhalation hazards including toxic gases and particulate matter. But, on the other hand, this is not reflected with the blatant inconsistency in complying with surgical smoke evacuation recommendations. It is no surprise that the smokers have a higher prevalence of emphysema and bronchitis. Smokers are less likely to work in pediatric facilities, probably because of the intense prohibition of smoking at those facilities, while participants with more experience are less likely to be smokers, probably because of the geographic difficulty in taking a smoking break while working in surgery. Support for AORN recommended practices is significantly different between non-smokers and smokers ($p = 0.021$). Non-smokers answer "always" more often and smokers answer "never" more often. This is not surprising since non-smokers usually want to be in a clean air environment verses smokers who may not consider inhaling surgical smoke as being hazardous.

The theoretical framework guiding this study is the Diffusion of Innovations theory, which provides a valuable and respected model that addresses innovativeness

characteristics related to the adoption of healthcare practices (Rogers, 2003). The foundation for this study that examines predictors for compliance with smoke evacuation recommendations consists of the basic innovative characteristics in the Roger's model that include individual innovativeness characteristics, perceptions of the innovation attributes, and the organizational innovativeness characteristics. Even though only seven of the 13 hypotheses are strongly supported, the Rogers model serves as a sound foundation for this study. Since hypotheses in each of the three sections are supported, the linkage of using all three divisions involving the individual characteristics, perceptions of the attributes, and the organization characteristics provide adequate evidence to confirm the Roger's model for this research. Further research can be conducted to more closely examine those hypotheses that were not supported.

The three divisions provide a logical format to discuss each hypothesis to determine the influence on compliance with smoke evacuation recommendations. This approach helps to organize the results and comments for better understanding and significance.

Individual Innovativeness Characteristics

H1. **As the ages of perioperative nurses increase, compliance with surgical smoke evacuation recommendations decreases.**

This hypothesis is not supported by this research. Even though the only one significant finding reports that older nurses use the inappropriate smoke evacuation method of suction only during tonsillectomy procedures, age did not appear to be significantly linked to whether appropriate or even inappropriate smoke evacuation

methods are used. This finding contradicts previous studies noting that younger persons more readily adopt new technology and practices (Brancheau & Wetherbe, 1990; Hebert & Benbasat, 1994; Rivers et. al., 2003; Vaughn et al., 2004). Because of the inconsistent practices of compliance with smoke evacuation recommendations, it is not surprising that age does not make any difference with compliance.

H2. **As the number of years of formal education for perioperative nurses increase, compliance with surgical smoke evacuation recommendations increases.**

When the results are analyzed, the level of education does not appear to be strongly linked to the implementation of smoke evacuation recommendations; therefore, this hypothesis is not supported with the results of this study. This finding does not conform to previous studies that demonstrate more highly educated personnel are more apt to be early adopters of new technology or practices (Brancheau & Wetherbe, 1990; Hebert & Benbasat, 1994; Lia-Hoagberg et. al., 1999; Rivers et. al., 2003; Vaughn et al., 2004). Maybe the barriers to practice that are identified in this study (physicians, availability of the smoke evacuation equipment, noise of the equipment, or staff complacency) are so powerful that even more highly educated nurses are not able to fully implement smoke evacuation recommendations. The inconsistencies in smoke evacuation practices may be so great that age and years of education just cannot have a significant impact on compliance with surgical smoke evacuation recommendations.

H3. **When the amount of experience, knowledge, and training regarding surgical smoke evacuation increases, compliance with surgical smoke evacuation recommendations increases.**

This hypothesis is partially supported with the study results. The amount of experience is the part that is not supported as influencing compliance with smoke evacuation recommendations. This finding contradicts the outcomes from previous research that shows more experienced nurses more readily adopt technology or use evidence-based practice recommendations (Brancheau & Wetherbe, 1990; Hebert & Benbasat, 1994; Lia-Hoagberg et. al., 1999; Rivers et. al., 2003; Vaughn et al., 2004). This may be from complacency often felt by experienced nurses, especially when devices, such as smoke evacuators are not even available for use. Sometimes experienced nurses may feel that they have been breathing surgical smoke for years, so why start evacuating it now?

The amount of knowledge and training is found to have a significant effect on compliance with surgical smoke evacuation recommendations so that part of the hypothesis is strongly supported. The more knowledge a nurse has acquired through attending educational offerings, through readings (articles, chapters, study guides, AORN Recommended Practices, AORN Position Statement), and through training programs, smoke evacuation recommendations are implemented more often. This is an expected outcome that is based on previous literature demonstrating that adequate training and attendance at educational offerings are positive predictors of adherence to

recommended practices (Lia-Hoagberg et. al., 1999; Rivers et. al., 2003; Vaughn et. al., 2004).

Results of this study also reflect that for some procedures, such as mastectomy or hemorrhoidectomy (using a smoke evacuator), nurses who answered that they attended more than ten educational offerings score significantly higher than all other groups. This finding is consistent with prior research results reflecting that increased education impacts whether a person adopts new technology or practices. The same is demonstrated with the number of readings and the amount of training received. There are significant relationships reported between certification and smoke evacuator use for different procedures. This relationship is logical as one would expect a certified nurse to comply with research-based recommendations. The strong relationship between the nurse reading the AORN recommended practices that address smoke evacuation and the AORN Position Statement on Surgical Smoke and Bioaerosols and the use of a smoke evacuator and suction with an inline filter for various procedures reveals that nurses are paying attention to the recommended practices and statements that AORN publishes. There is absolutely no linkage between nurses unfamiliar with the AORN recommended practices and the AORN position statement with the independent variable noting more compliance with smoke evacuation recommendations. AORN continues to successfully lead the way in providing its membership with documents, information, and education to encourage safe practices and a healthy surgical workplace. Those nurses who use this information are the ones who are more passionate about employing smoke evacuation practices as recommended.

H4. **When the incidence of reported respiratory problems by perioperative nurses increases, compliance with surgical smoke evacuation recommendations increases.**

Many nurses report the presence of respiratory problems that may be caused or exacerbated by inhaling surgical smoke. When compared to the prevalence of different respiratory conditions in the United States, the nurses' prevalence as noted in this study is greater for each condition. Table 8 illustrates the comparison between what the prevalence of reported conditions by the nurses in this study to the prevalence in the United States.

Table 8. Prevalence Comparison of Respiratory Conditions

Respiratory condition	Prevalence in study	Prevalence in USA*
Allergies	24.23 percent	18.38 percent
Sinus infections/problems	22.93 percent	10.33 percent
Asthma	10.87 percent	6.4 percent
Bronchitis	9.04 percent	4.45 percent

*Note. Prevalence percentages. From "Prevalence and incidence." By Wrong diagnosis. 2009. Retrieved March 25, 2009, from http://www.wrongdiagnosis.com.

The perioperative nurses may be experiencing higher prevalence ratings because of continual inhalation of surgical smoke. Some of these prevalences for the nurses in the study are even more than twice the prevalence in the United States. This information should be reason for concern in that inhaling surgical smoke has been known to cause each of these respiratory conditions. Information such as this should be

part of an educational program that highlights the hazards of breathing in surgical smoke. If nurses realize the impact of the negative consequences of surgical smoke exposure, then they probably would be more passionate about evacuating all plume generated in surgery.

Even though the relationships between individual symptoms and acceptable smoke evacuation methods are inconsistent, there does appear to be a weak relationship between the presence of symptoms and smoke evacuation compliance. Expectations are that nurses exhibiting respiratory problems would be more apt to evacuate surgical smoke using appropriate methods. For example, nurses with breathing difficulties have a score 0.238 higher for "mastectomy – suction only" meaning that the nurse with breathing difficulties tends not to use the suction line only when evacuating smoke generated during a mastectomy as compared to a nurse without breathing difficulties. This is probably because a lot of surgical smoke is produced during a mastectomy. Using a suction line only is an inappropriate method to evacuate surgical smoke no matter what procedure is being performed. Inhaling the surgical smoke during mastectomy procedures could easily cause the nurse to have breathing difficulties. Individuals with nasal polyps have a score .959 lower for "condyloma – smoke evacuator" ($p<0.001$). This means that nurses reporting the presence of nasal polyps are less likely to use a smoke evacuator (which is the appropriate evacuation method). This finding is surprising because one would hope that nurses with respiratory problems would not want to inhale surgical smoke. Although individual symptoms are related to

various smoke evacuation practices, no relationships are consistent enough to be considered strong. Because of this inconsistency, the hypothesis is not supported.

Perceptions of the Smoke Evacuation Recommendation Attributes

H5. **When the perceptions of perioperative nurses are favorable regarding the attributes of relative advantage, compatibility, and observability of smoke evacuation recommendations, compliance with smoke evacuation recommendations increases.**

This hypothesis is supported by this research. The perceptions of the attributes of relative advantage (giving the nurse greater control over perioperative practices), compatibility (compatible with all aspects of the role of a perioperative nurse), and observability (using smoke evacuation recommendations fits into the nurses' work style) are strongly related to the implementation of surgical smoke evacuation recommendations. This supports the classic research by Hebert and Benbasat (1994) that demonstrates the strongest predictors of technology adoption are relative advantage, compatibility, and observability with approximately 77 percent of the variance being explained by these three variables. Hebert and Benbasat (1994) also suggest that the benefits of employing new practices should be clearly identified in developing the strategies for adoption. The benefits of smoke evacuation should strongly be promoted within educational pieces addressing surgical smoke. Helping nurses understand the positive outcomes associated with smoke evacuation and the negative ramifications of not using appropriate smoke evacuation practices should be an

essential part of educational programs and writings designed to increase the awareness of smoke evacuation hazards.

H6. **When perioperative nurses perceive the smoke evacuation recommendations as being complex, then compliance with smoke evacuation recommendations will be low.**

This hypothesis is supported by this research study. The perception of smoke evacuation recommendations being complex appears to be related to the implementation of smoke evacuation practices. This finding supports studies by Gilli and Lomas (1994) and Lia-Hoagberg et. al. (1999) that demonstrates when recommendations are more complex, then compliance will suffer. This confirms that recommendations must be easy to understand and implement in the clinical environment.

H7. **The higher the nurses rate specific barriers (as an obstacle to complying with smoke evacuation recommendations), the more likely the nurses are not going to comply with smoke evacuation recommendations.**

This hypothesis is not supported by the results of this study as the barriers considered in this section (noise, reliability, inconvenience, and cost) have been found not to be strongly related to compliance with surgical smoke evacuation recommendations. Noise, reliability of the smoke evacuator, and cost were shown to be associated with significantly lower scores for "suction only" being used for tonsillectomy and condyloma vaporization. This means that more nurses are using an inappropriate method of evacuation with the "suction only" practice while at the same time rating noise, equipment reliability, and cost as great barriers to smoke evacuation

practices according to the frequencies of the responses. Information about potential barriers to compliance still need to be included in smoke evacuation lectures so that the nurses are aware that they possibly could impact the implementation of smoke evacuation practices.

Organizational Innovativeness Characteristics

H8. **When organizations are large in size, compliance with smoke evacuation recommendations increases.**

This hypothesis is supported in this study in that there is a positive relationship between larger institutions and compliance with smoke evacuation recommendations. Analyzing the number of operating rooms and the number of cases reflect this support. Facilities with fewer operating rooms scored significantly less than larger facilities when linking them to certain procedures and the compliance with smoke evacuation recommendations. This outcome also is found when considering the number of surgical procedures performed. These results are consistent with the outcomes reflected in a study by Estabrooks et. al. (2007) that notes larger hospitals demonstrate a higher level of research utilization in practice.

Also of interest is that nurses working at magnet facilities are more inclined to comply with smoke evacuation recommendations as compared to those who work in non-magnet facilities. This is not a surprising finding as Karkos and Peters (2006) determined that the barriers to research utilization are less within magnet hospitals.

H9. **When organizations exhibit greater complexity, compliance with smoke evacuation recommendations increases.**

Complexity is measured in this study by the number of different specialties available at a facility. This study supports the hypotheses that locations offering a greater number of specialties (increased complexity) have increased compliance with smoke evacuation recommendations. Rogers (2003) professes that when organizations have a large number of different specialties, there is increased organizational innovativeness. This study concurs with that finding. When surgical arenas offer a variety of specialties, then increased proficiencies and skills are required, that, in turn, may foster more reliance and compliance on research-based recommendations. This may be because one specialty may have a powerful influence on others. For example, plastic surgeons usually are passionate about the need to evacuate surgical smoke. They may have great influence on the other specialty surgeons and surgical team members to encourage them to evacuate surgical smoke. As the number of specialty services increase, there may be more pressure from within particular groups to evacuate surgical smoke. On the other hand, a hospital that only provides orthopedic and podiatry services may not evacuate surgical smoke as consistently since fewer services are offered and less pressure from other services is present.

H10. **When organizations exhibit greater interconnectedness, compliance with smoke evacuation recommendations increases.**

This study supports this hypothesis. Greater interconnectedness and collaboration appear to be associated with greater implementation of smoke evacuation recommendations. Brancheau and Wetherbe (1990) note that strong interpersonal channels of communication are needed for the successful adoption of technology while

Grimshaw et. al. (2001) verified that increased interconnectedness is more effective in changing practices. This study supports those findings. But Waddell states that some studies note that even with intensive dissemination and communication, some guidelines are just not fully implemented into practice (2002) or, as shown in the Grimshaw et. al. study, are only partially implemented (2004). It is logical that nurses would hope that increased communication would always have a positive impact on compliance with research-based recommendations.

H11. **When organizations show leadership support, compliance with smoke evacuation recommendations increases.**

This study supports this hypothesis and also concurs with findings from other studies. For example, a study by Marchionni and Ritchie (2007) supports that effective leadership is linked to successful change processes. Hebert and Benbasat (1994) propose that leaders should be identified to include them in the change process of technology adoption. Kajermo et. al. report that lack of leadership support is a perceived barrier to the implementation of research-based practices (2007). Rycroft-Malone finds that responsive administration leads to support for innovation utilization (2007). Other studies in Chapter II reference research findings that document the strong relationship of management support in the implementation of new practices.

When leaders support compliance with smoke evacuation recommendations, it would appear logical that appropriate smoke evacuation practices would be employed. One of the obstacles to implementing smoke evacuation practices is found to be the physician as noted in the study at Duke University (Edwards & Reiman, 2008) and also

in this study. This topic is often the main discussion point at conferences when obstacles to using smoke evacuation devices are debated.

H12. **When organizations have a high level of formalization, then compliance with smoke evacuation recommendations will be low.**

This hypothesis is not supported in this study. Formalization includes bureaucracy and a number of levels of management that provide barriers to rapid implementation of research-based recommendations. Rogers notes that formalization and bureaucracy have negative effects on organizational innovativeness (2003). The number of levels of management above the nurse and above the director in this study does not seem to be strongly related to the implementation of smoke evacuation recommendations.

Also the type of healthcare facility and the type of surgical facility are analyzed when testing this hypothesis. In Chapter II (review of literature), previous research notes that academic facilities tend to eliminate barriers to learning and actively promote education in the pursuit of innovation and new practice adoption (Marchionni & Ritchie, 2007). Rycroft-Malone et. al. (2002) also propose that research use in healthcare facilities (such as using evidence-based recommended practices) is more apt to occur in learning institutions, such as academic settings. However, in this study working in an academic setting is not significantly linked to compliance with smoke evacuation recommendations; however, academic facilities scored higher than military/government facilities with the proper evacuation of surgical smoke. Also noted is that healthcare facilities in urban settings are much more apt to comply with smoke

evacuation recommendations than rural settings. This is a surprising finding that is addressed in the next section.

H13. **The higher the nurses rate specific organizational barriers (as an obstacle to complying with smoke evacuation recommendations), the more likely the nurses are not going to comply with smoke evacuation recommendations.**

This hypothesis was not supported in this study. The findings are inconsistent when regression analysis is employed but when each barrier is individually graphed noting the frequencies of responses, the barriers being perceived as the greatest are equipment availability, physicians, noise, and staff complacency. This information is valuable when determining the barriers to compliance so that they can be addressed as smoke evacuation recommendations are implemented. Strategic plans need to be discussed to handle barriers to implementation so that a smoke evacuation program can be fully implemented.

Additional analyses leads to the conclusion that individual innovativeness characteristics are more strongly linked to the use of the smoke evacuator and the inline filter while perceptions of the attributes of the smoke evacuation recommendations and organizational innovativeness characteristics are not as strongly linked. This finding concurs with what Marchionni and Ritchie found in 2007 in that there is only beginning evidence that guideline implementation is influenced by organizational culture and leadership. Also Estabrooks et. al. (2007) conclude that organizational factors contribute little as compared to individual characteristics when assessing research utilization. Estabrooks et. al. (2007) also remark that unscrambling the influence of

organizational complexities is a very complex process and requires a lot of time and money. Organizational innovativeness characteristics continue to be explored but their true significance has yet to be validated.

Unanticipated Outcomes

Unanticipated outcomes or surprises sometimes are found in research studies. There were some surprises that are present in this study. They are described below.

There is very strong evidence that hospitals in rural settings (population less than 50,000) implement smoke evacuation recommendations at a much lower rate than urban hospitals (population more than 50,000). With the evolution and promotion of internet learning, advancements in communication, and availability of publications on surgical smoke hazards, there should be no difference in compliance with surgical smoke evacuation recommendations between these two types of facilities. In the courts today, healthcare professionals are held liable for following national standards instead of local standards since advancements in transportation and communication methods have made attending conferences and maintaining professional skills easy to achieve. Therefore, rural settings are now held to the same standards as urban areas so there should be no significant difference in compliance with any research-based recommendations. However, rural hospitals may not have the funds to provide adequate smoke evacuation equipment and supplies as compared to urban facilities.

H10 states that when organizations exhibit greater interconnectedness, compliance with smoke evacuation recommendations increases. There were some odd findings when this hypothesis is tested. Specifically, higher levels of satisfaction are

associated with greater use of "suction only" for many procedures as well as being associated with higher levels of use of other smoke evacuation methods. It's surprising that some nurses who use suction only for smoke evacuation (an inappropriate method of smoke evacuation) also exhibit high levels of satisfaction with this practice. This outcome could be the result of nurses just not understanding the problems with using "suction only" for smoke evacuation. The "suction only" practice may visibly remove the smoke particulate from the air but pulling the smoke particulate directly into the wall or ceiling suction will begin to occlude the suction lumen, thus decreasing the effectiveness and efficiency of the suction. The suction line could even become totally occluded from the smoke debris, which could cause major patient injury or even death if a life-threatening situation occurs that requires strong suction. Therefore, the "suction only" method of evacuation should never cause nurses to be satisfied with this practice. Education can help to increase the nurses' understanding of this concern so that "suction only" practices are avoided.

When H12 is tested regarding formalization and compliance with smoke evacuation recommendations, the type of surgical facilities are also analyzed. A surprising outcome reveals that freestanding surgery centers score higher than surgical departments within hospitals for compliance with smoke evacuation recommendations. This finding is surprising as there should not be a significant difference between the two types of surgical facilities. However, this information can be used to justify the initial targeting of lectures on surgical smoke hazards to hospital surgery departments. In addition, in 2009 research is lacking that compares compliance with general research-

based recommendations between freestanding surgery centers and hospital surgical departments. Future research could be conducted to address this comparison.

Another surprise is that almost half of the hypotheses are not supported in this study, probably because the inconsistencies of compliance with smoke evacuation recommendations are so great that there is too much noise. Some of the specific indicators for this study just do not have any effect on compliance with smoke evacuation recommendations. Even though prior research results are used to set the direction of the different hypotheses, findings from this study do not support all of these predictions. Increased formal education in this study does not have a significant effect on compliance with surgical smoke evacuation recommendations but prior research notes that increased education often leads to greater acceptance and adoption of new technology or practices (Vaughn et. al., 2004). Formal education may not be a key predictor of compliance in this study but increased education specifically on surgical smoke hazards and evacuation has a direct effect on compliance with smoke evacuation recommendations. Also specific barriers are not found to have a significant influence on compliance with smoke evacuation recommendations. Kajermo et. al. (2007) note that identifying barriers or obstacles that influence the adoption of innovations are critical in determining activities to promote evidence-based practices. Even though some of the frequency ratings of specific barriers are high in this study, significance is not achieved when proposing that identified barriers encourage or discourage compliance.

When the percentages of responses are reviewed for the dependent variable questions on smoke evacuation practices, surprising results reflect that smoke evacuators are not used for most of the procedures. For example, for total hip replacement, smoke evacuators are never used as reported by 69 percent of the responses, inline filters are never used as reported by 56 percent, and suction only is used always as reported by 31 percent of the responses. The procedures of mastectomy, tonsillectomy, hemorrhoidectomy, laparoscopic dissection, microlaryngoscopy for vocal cord polyp removal, and colonoscopy all had similar findings with the smoke evacuator and inline filter never being used as reported by high percentages of the responses. This demonstrates that appropriate methods to capture and filter the surgical plume are not being consistently practiced. On the other hand, responses for the use of a smoke evacuator for condyloma vaporization are 54 percent always, 45 percent never for inline filter use, and 40 percent never for suction only use. This surprising outcome does not coincide with the other procedures and methods of evacuation. This finding may reflect that perioperative nurses understand the hazards and pathogen transmission potential when inhaling surgical smoke with viral contamination. Also vaporization of condyloma in the past was often performed using a carbon dioxide laser. When lasers are used, nurses tend to realize the need to evacuate the surgical smoke so smoke evacuators are usually available and employed for these procedures. In 2009 many surgeons have resorted to using the electrosurgery device for condyloma vaporization because this device is more readily available. Many times smoke evacuators are not accessible due to a limited inventory; therefore, smoke evacuation is not used as often.

Again, this data notes the inconsistencies of smoke evacuation practices in surgical environments today.

Conclusions

With over half of the hypotheses being supported in this study, significant key indicators that predict compliance with smoke evacuation recommendations are identified. The following predictors have been shown to have a direct influence on promoting compliance with surgical smoke evacuation recommendations:

- Increased knowledge and training by the individual nurse
- Positive perceptions by the perioperative nurse on the attributes of smoke evacuation recommendations regarding relative advantage, compatibility, and observability
- Easy to understand and implement smoke evacuation recommendations (recommendations not being complex)
- Increased facility size
- Increased number of different specialties offered
- Greater interconnectedness
- Strong leadership support

Also highlighted by this study are the following:

- Urban facilities are is more compliant with smoke evacuation recommendations than rural facilities.
- Freestanding surgery centers are more compliant with smoke evacuation recommendations than hospital surgery departments.

- Academic settings are more compliant with smoke evacuation recommendations than military or government hospitals.

Weakly significant is the presence of respiratory symptoms that encourage compliance with smoke evacuation recommendations. For example, if a nurse has allergies, he or she would be more apt to comply with smoke evacuation recommendations.

The outcome of this study notes that of the three constructs, individual innovativeness characteristics are most strongly linked to compliance with smoke evacuation recommendations. Therefore, the individual nurse should remain the focal point when providing educational programs to change behaviors and practices in the operating room. Even though some organizational innovativeness characteristics are still important, they are just not as critical as the individual innovativeness characteristics.

The above list of predictors that are shown to promote compliance with smoke evacuation recommendations will be valuable in the design of educational offerings, writings, editorials, policy-formation, and competency programs. AORN, as a leader in promoting safe workplace environments, can use this valuable information in determining targets and creating plans to change practices within the operating suite. Companies selling smoke evacuation equipment and supplies can also use these key indicators to help target and educate surgical team members and their leaders so that hazards of surgical smoke are recognized and appropriate smoke evacuation practices are utilized. Industry can also target specific healthcare environments (smaller

facilities, hospital surgery departments) to begin the sales process that would place smoke evacuation devices in every surgical suite.

In conclusion, this study identifies the key indicators for compliance with surgical smoke evacuation recommendations. With the release of these critical findings that provide the foundation for comprehensive education about surgical smoke hazards and evacuation, the year 2009 can be targeted and designated as the "Year of Smoke Evacuation." The ultimate goal for the immediate future is to promote the evacuation of all surgical smoke so that clean air is constantly and consistently guaranteed in the surgical workplace. The time has come. The results are in. Effective smoke evacuation equipment and supplies are available in the healthcare market. The key indicators affecting compliance have been shown. Educational programs and action plans now can be designed to eliminate smoke from all surgical environments for the protection of perioperative nurses, physicians, other staff members, and patients.

Limitations

Limitations of this study include the threat to internal validity and the limited criteria for participation which can affect the study's generalizability to a larger perioperative nurse universe. Internal validity of a research study addresses the extent that the independent variables are actually influencing the dependent variable. In this study, history and expectancy may have an affect on internal validity as lectures and articles on the hazards of surgical smoke have been readily available in 2008 and 2009. This, in turn, may cause the participants to answer according to what they should be doing instead of what actually is being done to evacuate surgical smoke. To combat

this effect and to avoid biases, the survey questions are worded in such a way to avoid false answers. The instructions are written to stress that confidentiality is strictly maintained so that truthful answers are encouraged.

The criteria for participation limit the number of nurses who can participate. The requirement that the nurse be an AORN member may produce a nonequivalent group of perioperative nurses who are more apt to evacuate surgical smoke since they receive information about workplace hazards as a benefit of AORN membership. Also by using only AORN members, a threat to external validity of not being able to generalize the results to the larger AORN and non-AORN member population may be present. The survey could have been offered to nonmembers of AORN but results of the Duke survey published in 2008 supports a significant lack of appropriate smoke evacuation practices are found within the AORN nurse membership and within the non-AORN nurse membership (Edwards & Reiman, 2008). Future research can use the same survey tool with other providers, such as surgical technologists, anesthesia providers, and even surgeons. The results can then be compared to note similarities and contrasts to this study.

Implications for Action

The purpose of this study is to determine key indicators that are associated with different levels of compliance with smoke evacuation recommendations by perioperative nurses. The significant indicators identified in this study can now become part of intense educational programs designed to increase the awareness of surgical smoke hazards and promote compliance with evidence-based recommendations through

appropriate smoke evacuation practices. Even though these key indicators are but a small portion of an educational package, they provide direction that will lead to the most critical target audiences and then also provide guidance for the content development on surgical smoke hazards. For example, since the key indicators note that hospital surgery departments have lower compliance than freestanding surgery centers, a smoke hazards program geared towards the hospital surgery market could include the negative consequences of breathing surgical smoke, how to write an easy to follow smoke evacuation policy, and the importance of increased interconnectedness and leadership support within a facility for successful implementation of smoke evacuation recommendations.

The new AORN Surgical Smoke Tool Kit introduced at the 2009 AORN Congress helps perioperative nurses understand the hazards of surgical smoke and how to successfully comply with smoke evacuation guidelines. Also an article submitted for publication in the *AORN Journal* highlights the outcomes of this research so that nurses can access more details of the study and more fully understand what is needed to promote compliance. AORN in the past has been known as a recognized leader in promoting safe workplace environments. With this study identifying that leadership support is critical for compliance with smoke evacuation recommendations, AORN should educate the OR Directors and other leaders within the surgical arena on the strong relationship between proactive leadership and the implementation of surgical smoke evacuation recommendations. Key activities can be emphasized that enable the surgical leaders to support and promote compliance. Algorithms of practice can be

designed that incorporate surgical smoke evacuation with all procedures producing plume.

AORN has strong relationships with physician organizations. The information about surgical smoke hazards and compliance with smoke evacuation recommendations should become a topic of discussion with these organizations so that physicians are directed to offer support to nurses who want to comply with smoke evacuation practices. Physicians need to understand that even though they are only present in the operating room on specific days, perioperative nurses are exposed to surgical smoke on a daily basis. This is the reason perioperative nurses have become more passionate about this hazard than physicians as their exposure is much greater than that of physicians. Physicians also need to realize that nurses have indicated in this study that physicians represent a great barrier to the implementation of effective smoke evacuation practices. Therefore, activities must be created to change the negative attitude and behavior of some physicians regarding surgical smoke hazards and evacuation.

AORN has a close relationship with the different companies that manufacture or distribute smoke evacuation equipment and supplies. Identifying key indicators for compliance with smoke evacuation recommendations can be a welcome message for industry to help market and sell smoke evacuation devices. As this study reveals, availability of smoke evacuators and the noise level are both barriers to the implementation of smoke evacuation recommendations. Companies should promote that every surgical suite where plume is generated needs to have appropriate smoke evacuation capabilities. Also the smoke evacuator needs to be designed so it will

produce minimal amounts of noise. The surgical team must realize automatic sensors that immediately activate and deactivate the smoke evacuator when plume is created are also available. This helps to decrease the amount of continual noise generated in the operating room. The smoke evacuator's motor must be strong enough and responsive enough to provide immediate suction power so that no particulate escapes capture. The outcome of this study identifies key indicators involved with smoke evacuation devices and offers valuable information to smoke evacuation companies who strive to continually advance and enhance smoke evacuation systems.

Since increasing everyone's awareness about smoke evacuation is critical, AORN should hold a one-day roundtable discussion at the AORN headquarters for nurse leaders, surgeon leaders, safety and risk managers, and companies selling smoke evacuation devices. This type of meeting was held in the mid 1990s at the AORN headquarters and was very successful in introducing the initial campaign to promote smoke evacuation. Since that meeting more information from research studies is available that needs to be communicated so that the entire surgical team, other healthcare professionals, and industry colleagues understand the predictors and requirements for effective smoke evacuation practices.

When creating educational programs about surgical smoke, this study notes that the content needs to include the hazards of surgical smoke inhalation so that the relative advantage of using smoke evacuation practices is perceived to be better than not evacuating plume. Also demonstrating the ease of use of the smoke evacuation devices shows the nurses that smoke evacuation practices are compatible with the duties of a

perioperative nurse and fits easily into the workflow of a nurse. If the smoke evacuator is demonstrated, the nurses can actually observe the benefits of how the smoke evacuation devices effectively remove the particulate matter and toxic gases from the air. Testimonials provided by perioperative nurses who suffer from respiratory conditions associated with smoke exposure can be used to illustrate the negative consequences of smoke inhalation.

Educational programs on surgical smoke should be targeted for hospital surgery departments, rural areas, and hospitals that only offer a small variety of specialties. Web-based educational sessions can be designed since rural hospitals may not always be able to afford the costs of sending their nurses to conferences outside the rural area.

The importance of having a solid system of interconnectedness (the degree to which there are linkages through interpersonal networks) and collaboration must be promoted so that research-based recommendations can be implemented more successfully. Also leadership building must be provided so that OR leaders can appropriately react to support the implementation of new practices and innovations. By addressing these predictors, compliance with smoke evacuation recommendations for all plume-producing procedures can be more successful.

Finally this study reveals that nurses who have respiratory problems that may be connected to smoke inhalation are usually more alert to the need to evacuate surgical smoke. Nurses must be reminded that respiratory symptoms may be exacerbated by continual exposure to plume so smoke evacuation must be employed to provide clean air in the workplace. Providing testimonial accounts by nurses who are suffering

respiratory problems can be a very significant and powerful part of an educational program that promotes smoke evacuation.

Recommendations for Further Research

Studies focusing specifically on the hazards of surgical smoke and the implementation of surgical smoke evacuation recommendations are lacking. This study can be the springboard for more studies on this topic but with a different slant. Surgeons, anesthesia providers, surgical technologists, and non-AORN members can be surveyed in future research to see if their responses differ from those in this study. If the same survey tool is used, then a direct comparison can be made with the results. Of particular interest would be to see how other targeted groups would rate the various barriers that are known as obstacles to smoke evacuation use. Also this study can be used in other countries, such as Canada, to note if there are any differences in outcomes.

Another future study could be to compare compliance with surgical smoke evacuation recommendations between free-standing surgery centers and surgery departments within hospitals to note any significant differences. If there is a difference, as shown in this study, more information would be needed to determine the reason for the difference. Local communities could be surveyed but a random sampling within a national target would be much more powerful for generalization of the findings to a larger population.

The outcomes of this study identify a number of key indicators that influence compliance with research-based smoke evacuation recommendations. Could these same significant predictors be applied to compliance with other research-based

guidelines? For example, could noting compliance with laser eye protection recommendations be affected by the same predictors that are identified in this study? As previously mentioned, a future study could use the same survey tool but a different research-based recommendation to see if the results are similar. Different parts of the survey, such as specific barriers would have to be modified to relate to the recommendation. The outcome of this future study would help to identify significant key indicators for compliance with any research-based recommendation no matter what the topic.

An experimental study about surgical smoke inhalation and the presence of respiratory symptoms could be conducted by designing a lapel indicator that would measure the particulate that the provider is exposed to each day when using the smoke evacuator and when a smoke evacuator is not available. This would provide very insightful and valuable information to help document the inhalation hazards of surgical smoke and promote smoke evacuation.

Since Estabrooks et. al. (2007) conclude that more research needs to be conducted on the influence of organizational innovativeness characteristics, future research focusing on this concern would help to decipher some of the organizational complexities that directly impact the implementation of research-based recommendations.

Since the AORN Surgical Smoke Evacuation Tool Kit has been introduced along with the results of this study at the March 2009 AORN Congress, a repeat of this study could be conducted in 2010 to note if there are significantly different responses.

Since AORN is dedicated to promoting smoke evacuation practices through the tool kit introduction, articles, and other communications, the results of a repeat study could help to determine the effectiveness of this smoke evacuation campaign.

Concluding Remarks

Surgical smoke will continue to invade our surgical suites if appropriate smoke evacuation practices are not employed. Perioperative nurses exposed to surgical smoke will continue to be at high risk for the development of respiratory problems if this hazard is not addressed appropriately. No longer should the nurse be treated as the canary who serves as the biological indicator of poor air quality in mines. Hopefully an increase in respiratory problems in the perioperative nurse is not required before action is taken to mandate clean air in surgery.

The results of this study reflect key indicators associated with compliance with surgical smoke evacuation recommendations. This valuable information can be used to guide the path of educational programs, practices, and attitudes towards compliance with smoke evacuation recommendations. But there's a long way to go before surgical practices and attitudes about the need for smoke evacuation are consistent. The results of this study represent just one more piece in the puzzle of compliance with smoke evacuation recommendations. However, the identified key indicators provide a map to immediately begin the journey in pursuit of compliance.

As previously mentioned in Chapter II, Erin Anderson (2005) posed this powerful question (p. 103), "In hindsight, will health care professionals be embarrassed about their cavalier attitudes toward surgical smoke as they once were with cigarette

smoke?" The outcomes of this study have indicated that compliance with smoke evacuation recommendations continues to be lacking and comprehensive education about surgical smoke hazards continues to be needed. Until perioperative professionals become passionate about the evacuation of all surgical smoke, this hazard will continue to loom within the air in surgery and also in our lungs.

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Appendix A

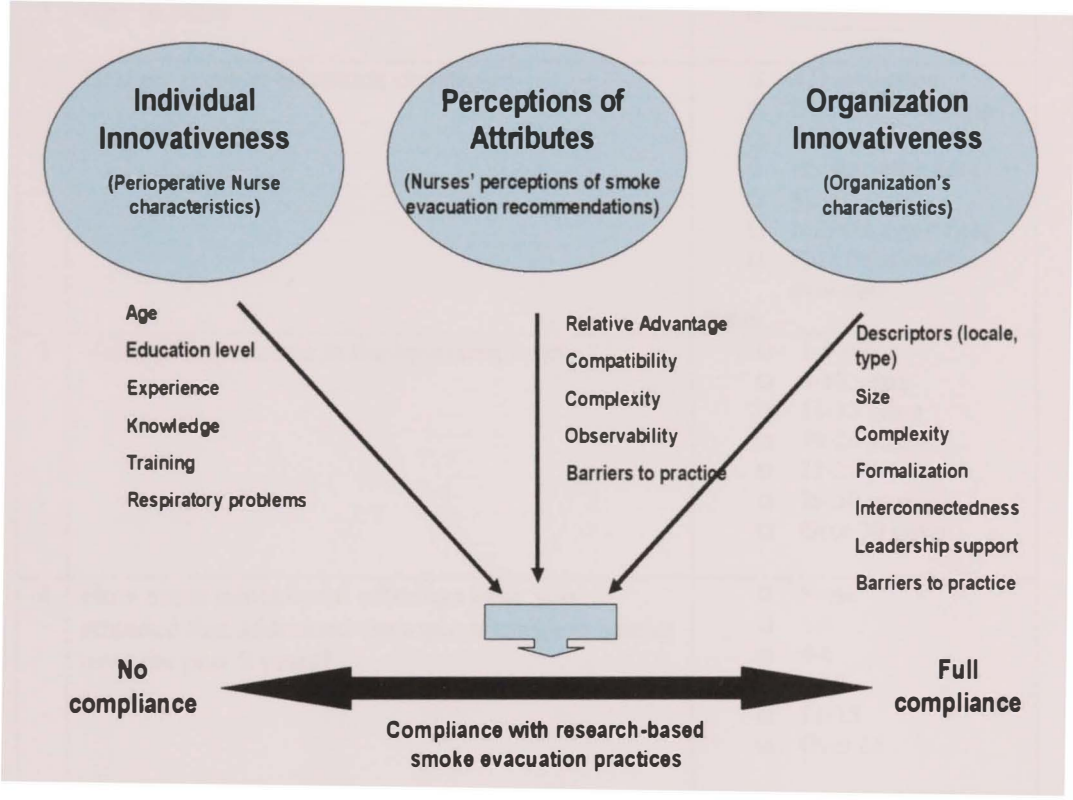
Surgical Smoke Evacuation Research Variables

Independent Variables	**Nominal**	**Dichotomous**	**Ordinal**	**Continuous**
Individual innovativeness				
Age				X
Level of education			X	
Yrs of experience				X
Educ offerings attended				X
Articles read				X
CNOR or CRNFA		X		
Formal training		X		
AORN RPs		X		
AORN Position Statement		X		
Self rate - Change agent			X	
Self rate - Control future			X	
Self rate – Venturesome			X	
Respiratory problems (list)		X		
Smoking status		X		
Pack years				X
Perception of innovation attributes				
Provide care efficiently			X	
Improve quality of environ.			X	
Easier to provide care			X	
Enhances effectiveness			X	
Greater control			X	
Compatible			X	
Fits well			X	
Fits work style			X	
Clear and understandable			X	
Easy to implement			X	
Easy to follow			X	
Noise as a barrier			X	
Reliability as a barrier			X	
Inconvenience as a barrier			X	
Cost as a barrier			X	

Variable	Nominal	Dichotomous	Ordinal	Continuous
Organization innovativeness				
Facility type 1 (Academic..)	X			
Facility type 2 (Hosp OR…)	X			
Locale (urban or rural)	X			
State	X			
Magnet status		X		
Number of ORs				X
Number of cases				X
Specialties offered		X		
# Mgt levels above staff				X
#Mgt levels above director				X
Interconnectedness questions			X	
Leadership support questions			X	
Physicians as a barrier			X	
Equipment avail as barrier			X	
OR Director as barrier			X	
Staff complacency as barrier			X	
Dependent Variable	**Nominal**	**Dichotomous**	**Ordinal**	**Continuous**
Smoke evacuation method used for various procedures			X	

Appendix B

Model Based on Rogers' Diffusion of Innovations



Appendix C
Perioperative Nurse Survey

	Descriptive Information	Response
1	Age in years	❑ _____
2	Highest level of education completed	❑ AD in nursing ❑ Diploma in nursing ❑ BSN ❑ BS/BA other field ❑ MSN ❑ MS/MA other field ❑ PhD/EdD/Practice doctorate Other_____
3	Years of experience in the operating room	❑ 1-5 years ❑ 6-10 years ❑ 11-15 years ❑ 16-20 years ❑ 21-25 years ❑ 26-30 years ❑ Over 30 years
4	How many educational offerings have you attended that addressed the topic of surgical smoke over the past 5 years?	❑ None ❑ 1-3 ❑ 4-6 ❑ 7-10 ❑ 11-15 ❑ Over 15
5	How many articles, chapters, or study guides have you read that addressed the topic of surgical smoke over the past 5 years?	❑ None ❑ 1-3 ❑ 4-6 ❑ 7-10 ❑ 11-15 ❑ Over 15
6	Specialty certification: CNOR CRNFA	❑ Yes ❑ No ❑ Yes ❑ No
7	Did you receive formal training specifically on the use of smoke evacuation equipment and devices?	❑ Yes ❑ No

8	Have you read the AORN Laser or Electrosurgery Recommended Practice regarding the evacuation of surgical smoke?	❑ Yes ❑ No
9	Have you read the AORN Position Statement on Surgical Smoke and Bioaerosols that was ratified by the 2008 House of Delegates?	❑ Yes ❑ No

On a scale from 1 to 10 with 1 being low and 10 being high, rate yourself as

10	Change agent	1	2	3	4	5	6	7	8	9	10
11	Able to control your own future	1	2	3	4	5	6	7	8	9	10
12	Venturesome (having a passion for innovations and advancements)	1	2	3	4	5	6	7	8	9	10

13	Have you experienced any of the following respiratory problems that may be associated with the inhalation of surgical smoke?	Allergies ❑ Yes ❑ No Asthma ❑ Yes ❑ No Emphysema-like conditions ❑ Yes ❑ No Breathing difficulties ❑ Yes ❑ No Increased coughing ❑ Yes ❑ No Increased nose bleeds ❑ Yes ❑ No

		Nasal congestion ❑ Yes ❑ No Sinus infection/problems ❑ Yes ❑ No Nasal polyp(s) ❑ Yes ❑ No Bronchitis ❑ Yes ❑ No Any diagnosed pulmonary disease/condition ❑ Yes ❑ No
	If you have experienced any other respiratory problems that may be associated with the inhalation of surgical smoke, please list here.	❑ Other_____
14	Are you currently a cigarette smoker?	❑ Yes ❑ No
	If yes...how many years have you smoked? ...how many cigarettes per day (average)?	❑ _____ ❑ _____
	If no, have you ever smoked?	❑ Yes ❑ No
	If yes...how many years did you smoke? ...how many cigarettes per day (average)?	❑ _____ ❑ _____

15	Facility type (please check the type of facility where you are employed for the greatest amount of your work time).	❑ Academic ❑ Non-academic, non-profit ❑ For profit ❑ Military/government/VA
16	Facility type (please check the type of facility where you are employed for the greatest amount of your work time).	❑ Surgical department within a hospital (inpatient or outpatient) ❑ Freestanding surgery center ❑ Surgical room in a clinic ❑ Surgical room in a physician's office ❑ Other_____
17	Please indicate the location of the facility where you are employed for the greatest amount of your work time.	❑ Rural (population less than 50,000) ❑ Urban/Suburban (population more than 50,000)
18	State of primary employment	❑ _____
19	Do you work in a Magnet accredited facility?	❑ Yes ❑ No ❑ Don't know
20	Number of operating rooms in your surgery department.	❑ Less than 5 ❑ 5-10 ❑ 11-20 ❑ More than 20

21	Average number of cases per week in your surgery department.	❑ Less than 25 ❑ 26-50 ❑ 51-100 ❑ 101-150 ❑ 151-200 ❑ 201-250 ❑ More than 250

22	What surgical specialties are offered in your facility?	Bariatrics ❑ Yes ❑ No Cardiothoracic/ Vascular ❑ Yes ❑ No Dental/Oral Surgery ❑ Yes ❑ No ENT ❑ Yes ❑ No Gastrointestinal ❑ Yes ❑ No General Surgery ❑ Yes ❑ No Gynecology ❑ Yes ❑ No Neurosurgery ❑ Yes ❑ No Ophthalmology ❑ Yes ❑ No Orthopedics/Podiatry ❑ Yes ❑ No

		Pediatrics ❑ Yes ❑ No Plastic Surgery ❑ Yes ❑ No Surgical Oncology ❑ Yes ❑ No Transplant Surgery ❑ Yes ❑ No Trauma Surgery ❑ Yes ❑ No Urology ❑ Yes ❑ No

23	How many levels of management are above the staff nurse in your OR (to and including the OR Director)	❑ 1 ❑ 2 ❑ 3 ❑ 4 ❑ More than 4
24	How many levels of management are above your OR Director? (to and including the facility president)	❑ 1 ❑ 2 ❑ 3 ❑ 4 ❑ More than 4

Leadership support – Mark the response that indicates your agreement with each of the following statements.

		ALWAYS	SOMETIMES	NEVER
25	I get support from my OR Director when I implement AORN research-based recommended practices (in general).			
26	I get support from my OR Director when I implement AORN recommended practices regarding surgical smoke evacuation.			
27	I get support from my OR Director when I implement our OR policies and procedures regarding smoke evacuation practices.			
28	I get support from physicians when I implement smoke evacuation practices.			

The following statements are related to decision-making or interconnectedness. Please mark the number that best represents your response about decision-making in your OR.

Rate on a scale of 1 to 7:
Strongly Disagree (1)
Neutral (4)
Strongly Agree (7)

29	Nurses and physicians ***plan together*** to make the decisions about smoke evacuation practices.	1	2	3	4	5	6	7
30	***Open communication*** between physicians and nurses takes place as decisions are made about smoke evacuation practices.	1	2	3	4	5	6	7
31	***Decision-making responsibilities*** for smoke evacuation practices are shared between nurses & physicians.	1	2	3	4	5	6	7
32	Physicians & nurses ***cooperate*** in making decisions regarding smoke evacuation practices.	1	2	3	4	5	6	7
33	In making decisions about smoke evacuation practices, both ***nursing and medical concerns*** are considered.	1	2	3	4	5	6	7
34	Decision making for smoke evacuation practices is ***coordinated*** between physicians & nurses.	1	2	3	4	5	6	7

35	In making decisions about smoke evacuation practices, ***collaboration always occurs*** between nurses and physicians.	1	2	3	4	5	6	7
36	I am ***very satisfied with the way decisions are made*** about smoke evacuation practices (looking at the decision-making process not necessarily with the actual decisions.	1	2	3	4	5	6	7

The following statements are related to your perceptions of surgical smoke recommendations and technology. Please mark the number that best represents your level of agreement or disagreement with each statement.

Rate on a scale of 1 to 7:
Strongly Disagree (1)
Neutral (4)
Strongly Agree (7)

37	Complying with smoke evacuation recommendations enables me to provide care more efficiently.	1	2	3	4	5	6	7
38	Complying with smoke evacuation recommendations improves the quality of the environment where I work.	1	2	3	4	5	6	7
39	Using smoke evacuation recommendations makes it easier to provide surgical care.	1	2	3	4	5	6	7

40	Using smoke evacuation recommendations enhances the effectiveness of my role as a perioperative nurse.	1	2	3	4	5	6	7
41	Complying with smoke evacuation recommendations gives me greater control over my perioperative practices.	1	2	3	4	5	6	7
42	Using smoke evacuation recommendations is compatible with all aspects of the role I fill as a perioperative nurse.	1	2	3	4	5	6	7
43	I think following smoke evacuation recommendations fits well with the way I like to practice perioperative nursing.	1	2	3	4	5	6	7
44	Using smoke evacuation recommendations fits into my work style.	1	2	3	4	5	6	7
45	Smoke evacuation recommendations are clear and understandable.	1	2	3	4	5	6	7
46	I believe that it is easy to implement smoke evacuation recommendations to provide the care that I want to provide.	1	2	3	4	5	6	7
47	Overall, I believe that smoke evacuation recommendations are easy to follow.	1	2	3	4	5	6	7

The following are perceived barriers that prevent perioperative nurses from evacuating all surgical smoke. Please rate each barrier according to your perceptions.

Rate on a scale of 1 to 10:
Not a barrier (1)
Great barrier (10)

		1	2	3	4	5	6	7	8	9	10
48	Physicians										
49	Equipment not available										
50	Equipment is noisy										
51	Equipment is not reliable or ineffective										
52	OR Director										
53	Staff is complacent or lacks education about the need to evacuate plume										
54	Inconvenient										
55	Too costly										

For each of the following procedures using **electrosurgery**, please indicate how often you use each smoke evacuation method. If you are not involved with a particular procedure, then mark N/A (not applicable).

Always = 100% of the time
Often = 50-99% of the time
Sometimes = <50% of the time
Never = Not at all

Smoke evacuator = individual smoke evacuator
Suction line with inline filter = inline filter for surgical smoke evacuation placed within the suction line
Suction line only = no inline filter used on suction line

		Always	**Often**	**Some-times**	**Never**	**N/A**
56	Mastectomy – smoke evacuator					
57	Mastectomy – suction line with inline filter					
58	Mastectomy – suction line only					
59	Total hip replacement – smoke evacuator					
60	Total hip replacement – suction line with inline filter					
61	Total hip replacement – suction line only					
62	Tonsillectomy – smoke evacuator					
63	Tonsillectomy – suction line with inline filter					
64	Tonsillectomy – suction line only					
65	Vaporization of condyloma – smoke evacuator					
66	Vaporization of condyloma – suction line with inline filter					
67	Vaporization of condyloma – suction line only					
68	Hemorrhoidectomy – smoke evacuator					
69	Hemorrhoidectomy – suction line with inline filter					
70	Hemorroidectomy – suction line only					

		Always	Often	Some-times	Never	N/A
71	Laparoscopic dissection – smoke evacuator					
72	Laparoscopic dissection – suction line with inline filter					
73	Laparoscopic dissection – suction line only					
74	Microlaryngoscopy with removal of vocal cord polyp – smoke evacuator					
75	Microlaryngoscopy with removal of vocal cord polyp – suction with inline filter					
76	Microlaryngoscopy with removal of vocal cord polyp – suction line only					
77	Colonoscopy with biopsy – smoke evacuator					
78	Colonoscopy with biopsy – suction line with inline filter					
79	Colonoscopy with biopsy – suction line only					

Please submit your contact information to receive your $10 AORN gift certificate. Your personal information will be kept confidential and will not be associated with your responses in any way.

☐ No thank you

Name_____

Street address_____

City _____

State _____

Zip _____

Please contact bdittmer@aorn.org if you have any questions regarding this survey. Powered by Question Pro.

Appendix D
Letter of Invitation

Dear Perioperative Nurse Colleague,

I need your help. I am conducting a survey as part of my PhD research that will identify key indicators for compliance with surgical smoke evacuation recommendations. As you know, surgical smoke continues to be an aggravating, annoying, and unhealthy hazard in our operating room environments. Your honest and open answers to this survey will help in developing educational programs and tools to encourage compliance with smoke evacuation recommendations.

You have been chosen during a random sampling of AORN members who serve as staff nurses in the operating room. A $10 gift certificate to the AORN bookstore will be offered to the first 650 participants, so please don't delay in completing this survey. Your identifying information (name and address) will be separated from your survey responses so that confidentiality can be maintained. If you feel uncomfortable with answering any of the questions, then merely leave the response area blank. No foreseeable risks of participating in this survey are contemplated and any participant can withdraw at any time while completing the survey.

The preliminary results of this survey will be discussed at the 2009 AORN Congress session "Embracing Health: Stamping Out Surgical Smoke in Our Lifetime" that is scheduled for Monday, March 16th from 3:00-4:30PM in Chicago, IL. The results will also be submitted for publication in the *AORN Journal*.

Research in the area of compliance with smoke evacuation recommendations is very limited so this study is vital in addressing compliance concerns. **This survey only pertains to the evacuation of surgical smoke created when an electrosurgery device is being used since plume created by laser energy seems to be evacuated more consistently.** Your prompt and candid responses will be crucial in learning more about this issue and to help create a safe workplace environment in surgery. The average time to complete the survey is less than 15 minutes.

This survey has been approved by AORN and the Virginia Commonwealth University's Institutional Review Board. If you have any questions about your rights as a participant in this study, you may contact the Office for Research at Virginia Commonwealth University, [redacted]

You can access the survey now by clicking on the following website:
http://www.questionpro.com/akira/TakeSurvey?id=1102232

Thank you for your immediate participation in this study that will help lead to a safe surgical workplace environment.

Yours in nursing,

Kay Ball, RN, MSA, CNOR, FAAN
Past President, AORN
Chair, AORN Smoke Evacuation Task Force
PhD candidate, Virginia Commonwealth University

Appendix E
First Follow-up Reminder Letter

Dear Perioperative Nurse Colleague,

One week ago you received an e-mail invitation to participate in a research study by completing a survey. If you have completed the survey, then disregard this letter. This survey is part of my PhD research that will identify key indicators for compliance with surgical smoke evacuation recommendations. Your participation and candid responses are vital in learning more about compliance with smoke evacuation recommendations, which will help in developing educational programs and tools to encourage compliance.

You have been chosen during a random sampling of AORN members who serve as staff nurses in the operating room. A $10 gift certificate to the AORN bookstore will be offered to the first 650 participants, so please don't delay in completing this survey. Your identifying information (name and address) will be separated from your survey responses so that confidentiality can be maintained. If you feel uncomfortable with answering any of the questions, then merely leave the response area blank. No foreseeable risks of participating in this survey are contemplated and any participant can withdraw at any time while completing the survey.

The preliminary results of this survey will be discussed at the 2009 AORN Congress session "Embracing Health: Stamping Out Surgical Smoke in Our Lifetime" that is scheduled for Monday, March 16th from 3:00-4:30PM in Chicago, IL. The results will also be submitted for publication in the *AORN Journal*.

Research in the area of compliance with smoke evacuation recommendations is very limited so this study is vital in addressing compliance concerns. **This survey only pertains to the evacuation of surgical smoke created when an electrosurgery device is being used since plume created by laser energy seems to be evacuated more consistently.** Your prompt and candid responses will be crucial in learning more about this issue and to help create a safe workplace environment in surgery. The average time to complete the survey is less than 15 minutes.

This survey has been approved by AORN and the Virginia Commonwealth University's Institutional Review Board. If you have any questions about your rights as a participant in this study, you may contact the Office for Research at Virginia Commonwealth University, [redacted]
P.O. Box [redacted]

Please access the survey now by clicking on the following website:
http://www.questionpro.com/akira/TakeSurvey?id=1102232

Thank you for your immediate participation in this study that will help lead to a safe surgical workplace environment.

Yours in nursing,

Kay Ball, RN, MSA, CNOR, FAAN
Past President, AORN
Chair, AORN Smoke Evacuation Task Force
PhD candidate, Virginia Commonwealth University

Appendix G
Post study letter to those who requested the gift certificate

Dear Perioperative Nurse Colleague,

Thank you for responding to the survey, which is part of my PhD research, to identify key indicators for compliance with surgical smoke evacuation recommendations (title: Surgical Smoke Evacuation Guidelines: Assessing Compliance Among Perioperative Nurses). The survey was closed on January 30, 2009, with over 700 responses. The first 650 perioperative nurses who responded are receiving a $10 gift certificate.

This letter will serve as your coupon. Your coupon can be applied towards AORN products, services or event registrations. You can also apply it towards your membership renewal. Just submit this letter with your payment and order to AORN Customer Service. To contact AORN customer service: [redacted]

AORN Coupon #5000 **Coupon Value: $10.00**

The preliminary results of this survey will be discussed at the 2009 AORN Congress session "Embracing Health: Stamping Out Surgical Smoke in Our Lifetime" that is scheduled for Monday, March 16th from 3:00-4:30PM in Chicago, IL. The results also will be submitted for publication in the *AORN Journal*.

Your honest and open responses to this survey have helped to develop educational programs and tools to encourage compliance with smoke evacuation recommendations, such as the AORN Surgical Smoke Evacuation Tool Kit. This Tool Kit will be available online after its introduction at the 2009 AORN Congress in Chicago.

Thank you again for your participation in this survey. And thank you for promoting the evacuation of ALL surgical smoke to protect healthcare providers and patients.

Yours in nursing,

Kay Ball, RN, MSA, CNOR, FAAN